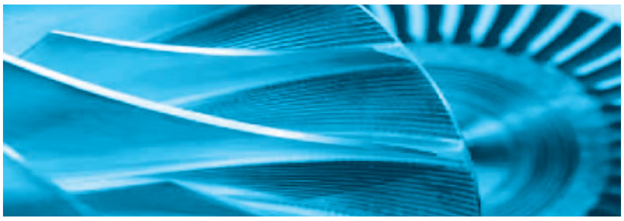
TCA
Project Guide

Exhaust Gas Turbocharger

Engineering the Future – since 1758.

MAN Diesel & Turbo



Project Guide

Exhaust Gas Turbocharger TCA-Series

Version 6/2007

Long Service Life of Wear Parts
Extended Application Range
High Power/Load Ratio
Easy Maintenance
Simple Installation
Safe Operation
Low Weight
Compact Design
Low Noise Levels

Turbine

- Optimized turbine blades, nozzle ring, insert and gas outlet casing
- Variable nozzle ring (optional)

Bearings

- High-grade thrust bearings for low mechanical losses
- Optimized shaft diameter for maximum efficiency
- Compact design of bearings for optimized damping characteristics

Compressor

- Optimized compressor wheel, diffuser and compressor volute
- Extended pressure ratio and airflow
- Patented compressor wheel seat for easy assembly

Maintenance

- Long inspection intervals
- Thrust-bearing inspection without shaft removal
- Compressor-wheel replacement without disassembly of the compressor casing and balancing afterwards
- Easy replacement of turbine blades
- Optional indicating system
- Reduced amount of components

Long Service Life of Wear Parts

- Floating radial bearings
- Rotating thrust bearing disk
- Design of nozzle ring
- Turbine blades
- Compressor wheel
- Optional: Compressor wheel made of titanium

Casing Design for Easy Assembly

- Uncooled casing
- Optional: Integrated post lubrication tank
- Lubrication via engine oil-lubrication system
- Integrated oil pipe and oil-venting system
- Integrated sealing-air supply

General

1

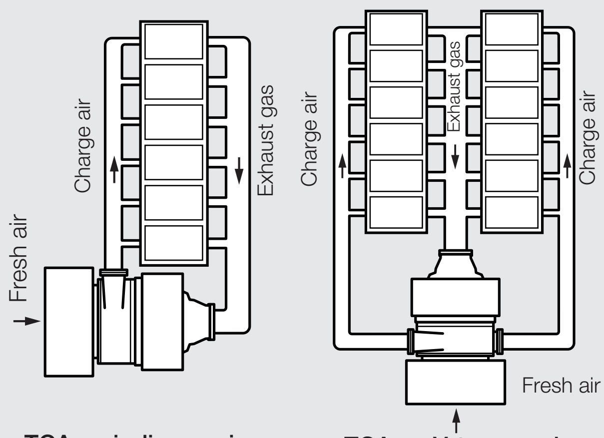
Characteristics of the TCA Series Exhaust Gas Turbocharger

Economic operation of modern large-scale engines without exhaust gas turbochargers is inconceivable. MAN Diesel turbochargers are equally tried and tested with marine main engines, auxiliary engines and in stationary systems under the most various operating conditions. Reliability, easy maintenance and long inspection intervals have been confirmed throughout decades of experience.

With the new TCA Series, expect not only clear increases in efficiency, but also substantial improvements in reliability and service life.

Exhaust gas turbochargers of the TCA Series can be used with two-stroke and four-stroke engines with constant-pressure charging and engine capacities from 2000 to 33000 kW per TC.

In many cases, the present necessity to realize the power adaptation on V-type engines via two exhaust gas turbochargers can be avoided by the comprehensive application range of the new TCA Series and the higher efficiency of the exhaust gas turbochargers. The characteristic diagrams of the TCA Series exhaust gas turbochargers indicate that a secure distance between surge line and operating characteristic line can be achieved on V-type engines, even with only one exhaust gas turbocharger.



TCA on in-line engine TCA on V-type engine

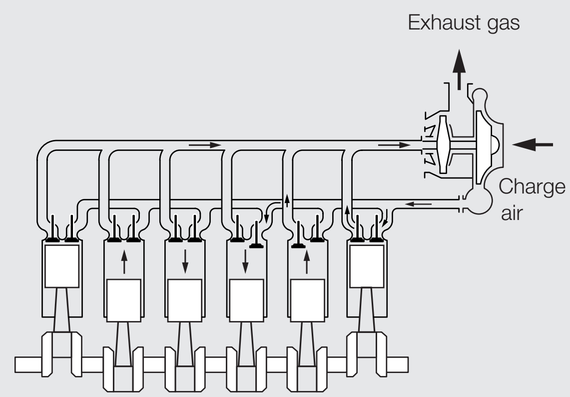
The modular design of the TCA Series allows for optimal adaptation of the turbochargers to the conditions for both four-stroke as well as two-stroke engines.

For each TCA-Turbocharger, both single-connection as well as double-connection compressor casings are available, enabling optimum results to be achieved in terms of design and economy.

Exhaust Gas Turbocharging

The exhaust gas turbochargers of the TCA Series are intended for constant-pressure charging.

With back-pressure charging, the engine exhaust gases flow into the exhaust manifold, are banked-up there and flow with constant pressure to the exhaust turbine.



Back-pressure charging

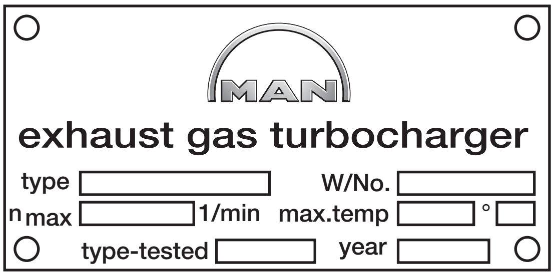
Performance Characteristics

The following modes of operation are distinguished: Generator curve (constant engine speed), propeller curve, propeller curve at reduced engine speed (excavator operation) and vehicle engine curve.

No matter in which mode of operation the engine is being used for a certain purpose, a secure surge line distance (difference between surge line and operating characteristic line) is always required. This is ensured by the respective dimensioning of compressor and diffuser.

Type Plate

The type plate is attached on the pressure socket of the compressor casing or on the sound insulation of the compressor casing, close to the pressure socket:



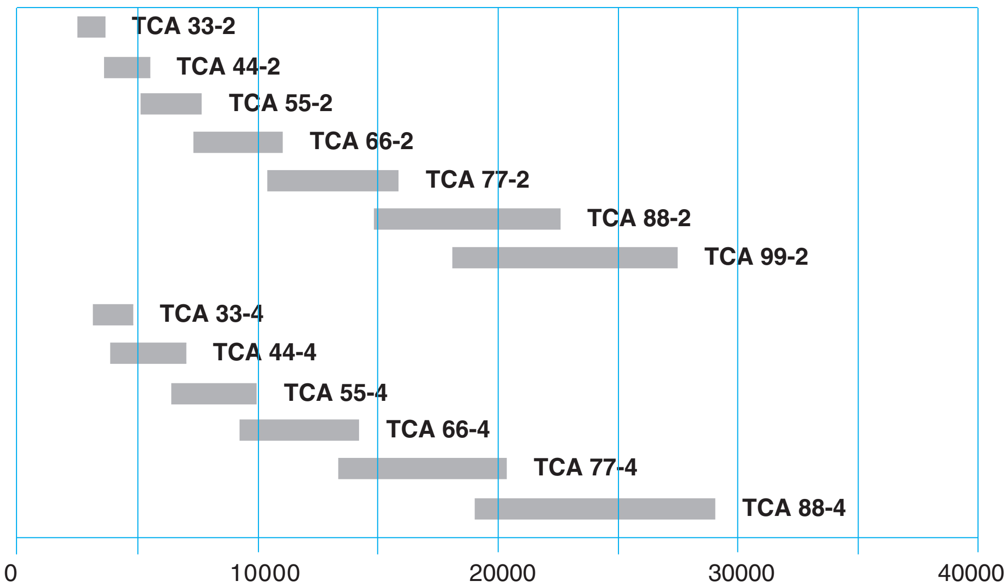
It contains the following information:

- Turbocharger type
- Works number
- Allowable rotor speed, max.
- Allowable turbine inlet temperature, max.
- Unit of temperature for the turbine inlet temperature
- Date of the type test
- Year of ex-works delivery

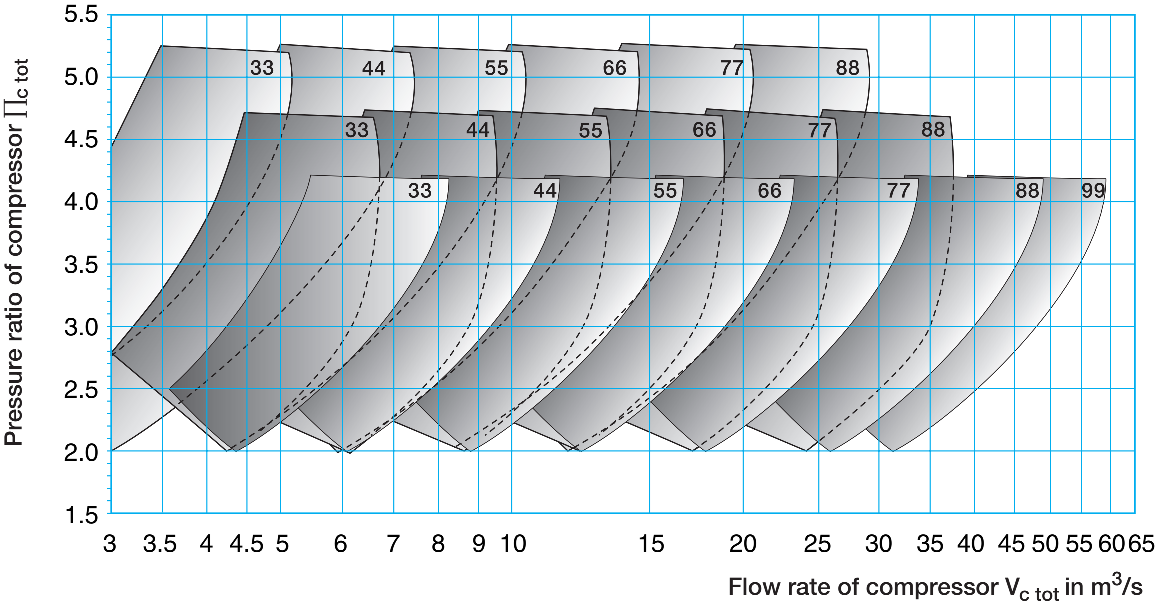
Currently the models TCA 55, TCA 66, TCA 77 and TCA 88 are each available as two-stroke and four-stroke version. Introduction/availability of other sizes on request.

Performance Ranges of the TCA Series

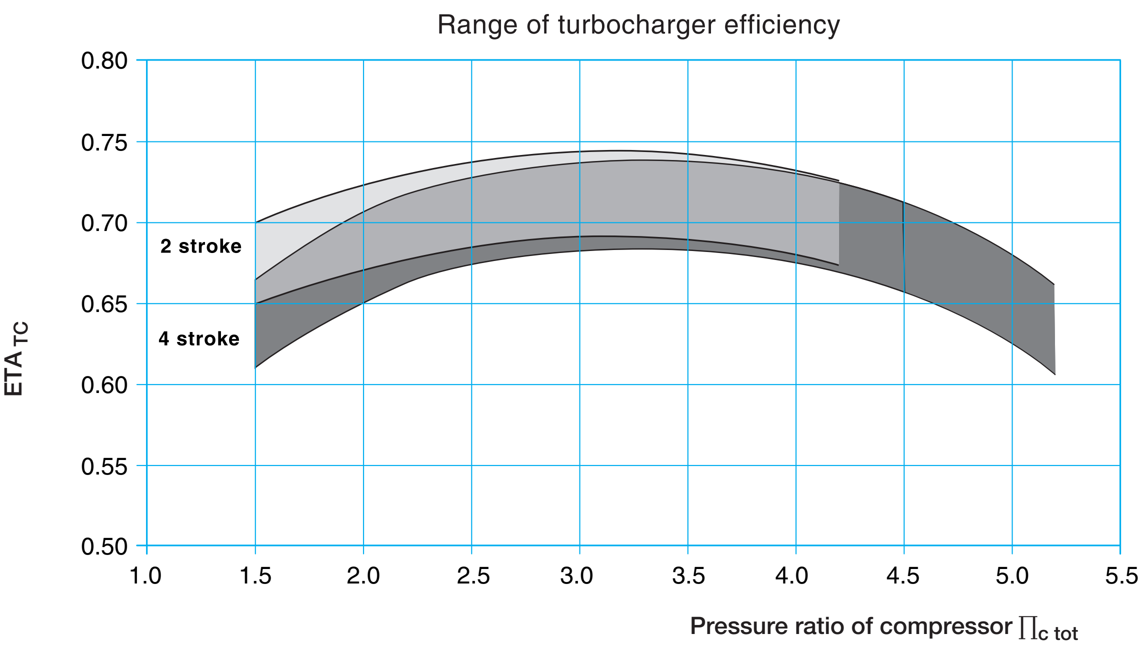
The state-of-the-art turbochargers designed and manufactured by MAN Diesel can be used in a very wide range for the charging of two-stroke and four-stroke diesel- and gas engines:



Engine output per turbocharger in kW for two-stroke and four-stroke engines

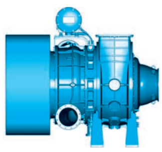
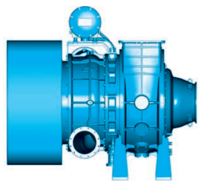
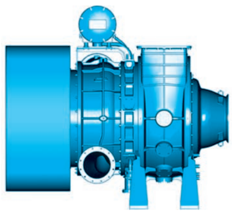


Turbocharger Application Range

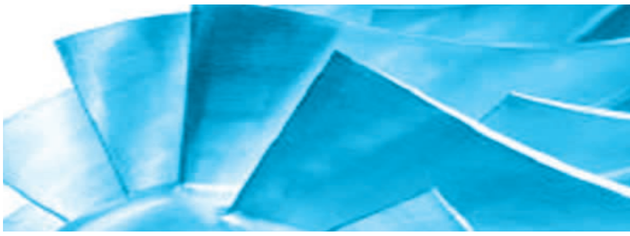


Range of Turbocharger Efficiency

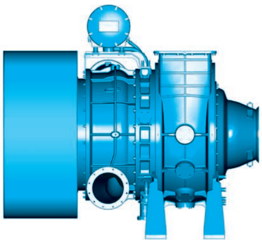
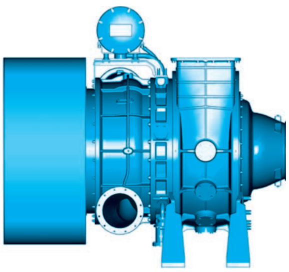
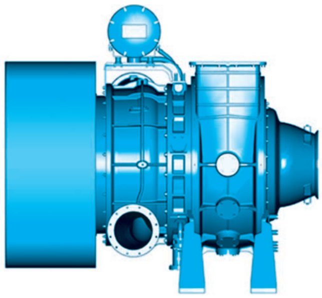
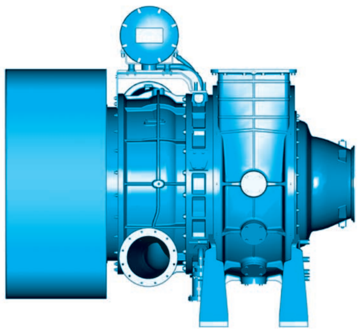
Overview of Series

Type	TCA 33	TCA 44	TCA 55
			
Technical Data			
Power of the charged engine per turbocharger			
Two-stroke engine ($l_e = 9$[1]) in kW	2 500 - 3 800	3 600 - 5 400	5 100 - 7 700
Four-stroke engine ($l_e = 7$[1] $\Pi_{max} < 4.2$) in kW	3 200 - 4 900	4 800 - 7 000	6 500 - 9 900
Four-stroke engine ($l_e = 7$[1] $\Pi_{max} < 4.7$) in kW	2 700 - 4 300	3 800 - 6 200	5 400 - 8 700
Total pressure ratio two-stroke/four-stroke in bar	4.0 - 4.2 / 4.5 - 4.7	4.0 - 4.2 / 4.5 - 4.7	4.0 - 4.2 / 4.5 - 4.7
Max. allowable rotor speed of turbocharger			
without disk cooling on 2-stroke engine in rpm	28 300	22 500	19 000
with disk cooling on 4-stroke engine in rpm	—	23 880	19 400
Max. allowable turbine inlet temperature in °C two-stroke/four- stroke	500 / 600	500 / 600	500 / 600

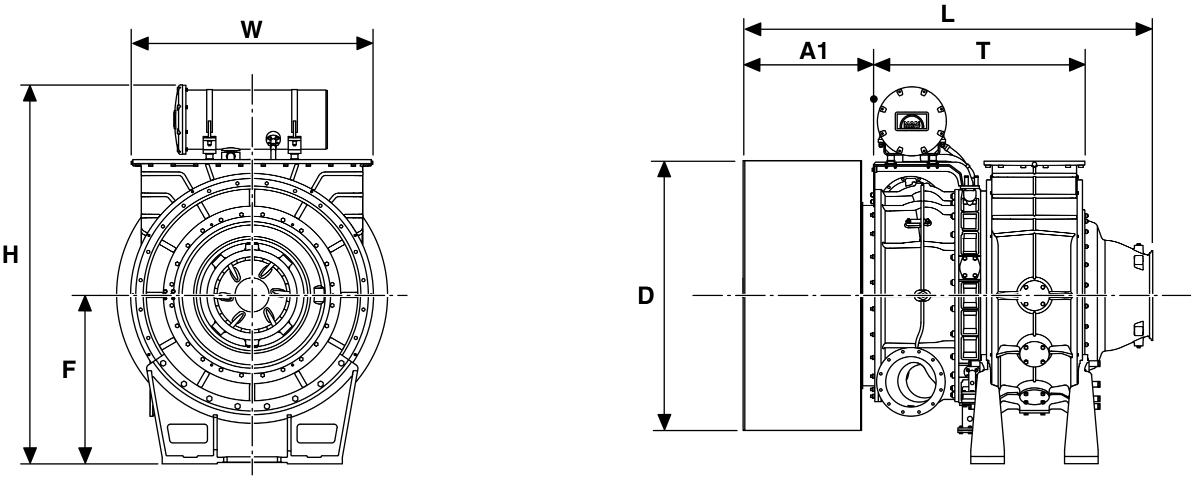
1) Spec. air consumption in kg/kWh

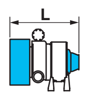
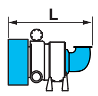


2

TCA 66	TCA 77	TCA 88	TCA 99
			
7 300 - 11 000	10 400 - 15 800	14 900 - 22 600	18 100 - 27 500
9 300 - 14 200	13 400 - 20 300	19 100 - 29 000	23 300 - 35 400
7 600 - 12 200	10 700 - 17 300	15 200 - 25 400	—
4.0 - 4.2 / 4.5 - 4.7	4.0 - 4.2 / 4.5 - 4.7	4.0 - 4.2 / 4.5 - 4.7	4.0 - 4.2 / 4.5 - 4.7
16 000 16 900	13 500 14 200	11 300 12 000	10 800 —
500 / 600	500 / 600	500 / 600	500 / 600

Dimensions and Weights



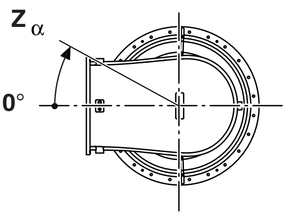
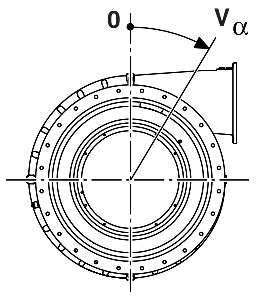
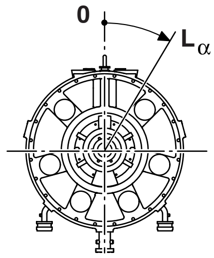
								
Type	**L in mm**		**W in mm**	**H in mm**	**F in mm**	**T in mm**	**A1 in mm**	**D in mm**
TCA 33		1 784	950	1 244				
TCA 44		2 123	1 120	1 495				
TCA 55	2 280	2 560	1 210	2 010 1)/1 900 2)	850 1)/740 2)	1 120	670	1 370
TCA 66	2 500	3 030	1 430	2 170	850	1 130	780	1 630
TCA 77	2 880	3 580	1 690	2 690 1)/2500 2)	1 200 1)/1 010 2)	1 580	920	1 930
TCA 88	3 370	4 220	2 010	2 970	1 200	1 880	1 080	2 270
TCA 99		4 586	2 508	3 259				

1) Casing feet, high
2) Casing feet, low

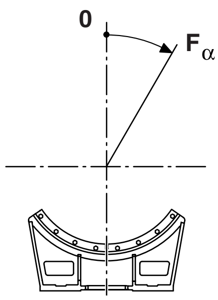
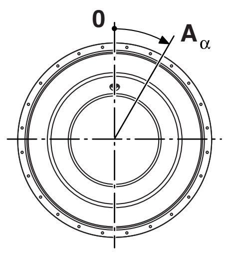
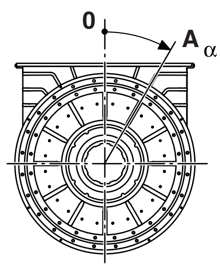
Weights of Assemblies	TCA 33 in kg	TCA 44 in kg	TCA 55 in kg	TCA 66 in kg	TCA 77 in kg	TCA 88 in kg	TCA 99 in kg
Emergency and post-lubrication system			75	140	200	285	
Casing feet, high low			282 235	340 —	733 548	740	
Silencer			427	800	1 770	2 010	
Bearing casing			516	910	1 500	2 500	
Intake casing			161	237	408	629	
Insert			142	198	250	400	
Compressor casing, single socket double socket			546 —	830 —	1 400 1 450	2 250 2 500	
Compressor wheel			39	66	115	200	
Gas-admission casing, 0° 90°			201 245	270 380	430 690	670 1 000	
Gas outlet casing			716	1 200	2 100	3 300	
Rotor gear			136	200	370	601	
Gas outlet diffuser			129	232	400	655	
Exhaust gas turbocharger, complete	1 140	1 970	3 370	5 500	9 250	15 500	20 450

Casing Positions

For the best possible adaptation to the engine, the five casing assemblies of the exhaust gas turbocharger as well as the casing foot can be delivered assembled in various angle positions relative to the vertical position. Other configurations are possible. For this, the exact fastening dimensions are required.

Gas-admission casing 1)						Compressor casing 1)						Bearing casing 1)					
																	
0°	15°	30°	45°	60°	75°	0°	15°	30°	45°	60°	75°	0°					
90°	105°	120°	135°	150°	165°	90°	105°	120°	135°	150°	165°						
180°	195°	210°	225°	240°	255°	180°	195°	210°	225°	2)							
270°	285°	300°	315°	330°	345°												

1) Casing positions viewed from the turbine side.
2) For position 240° to 345°, a separated oil tank is required

Casing foot 1)						Air intake casing 1)						Gas outlet casing1)					
																	
0°	15°	30°				0°	15°	30°	45°	60°	75°	0°	15°	30°	45°	60°	75°
75°						90°	105°	120°	135°	150°	165°						
						180°	195°	210°	225°	240°	225°						
	285°			330°	345°	270°	285°	300°	315°	330°	345°		285°	300°	315°	330°	345°

1) Casing positions viewed from the turbine side.

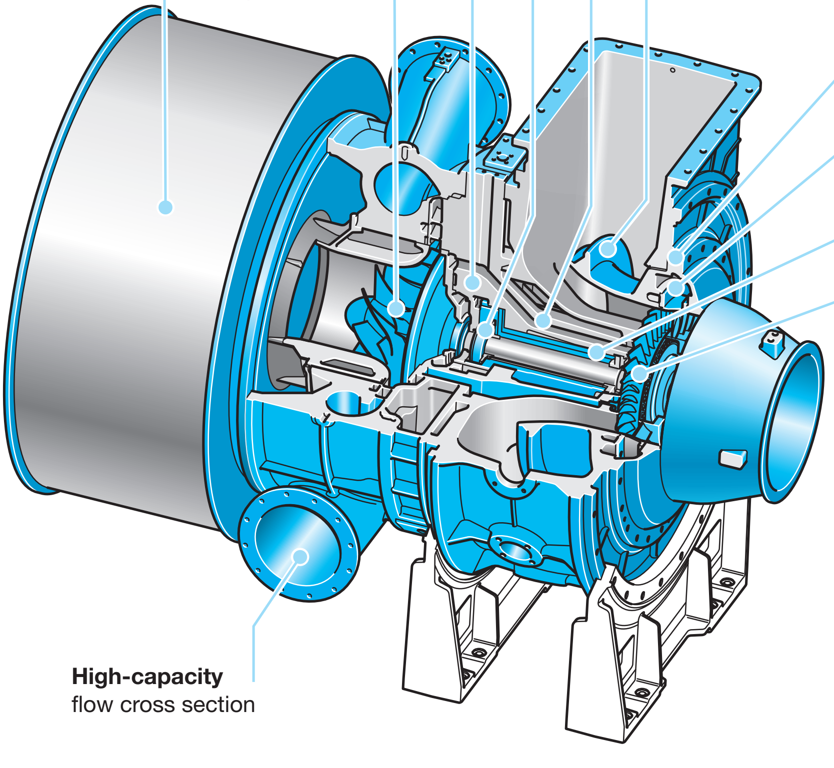
Design

3

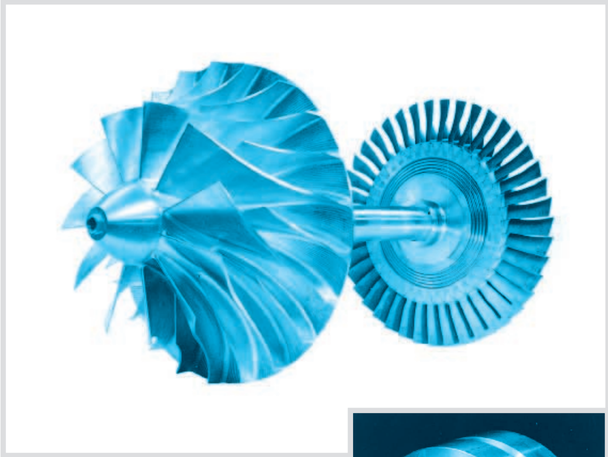
Characteristics of the Assemblies

The following view indicates the new design principle of the TCA Series:

- Whispering silencer
- Easy-to-service, low noise compressor wheel
- Uncooled casings
- Easy access to thrust bearing
- Integrated system for sealing air, lubricating and venting
- Highly-efficient, patented exhaust diffuser
- Long-life solid nozzle ring
- High performance plain bearings
- Highly-efficient turbine blades
- High capacity flow cross sections.



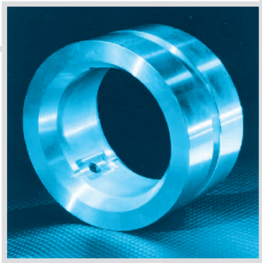
Compressor Wheel and Turbine Rotor



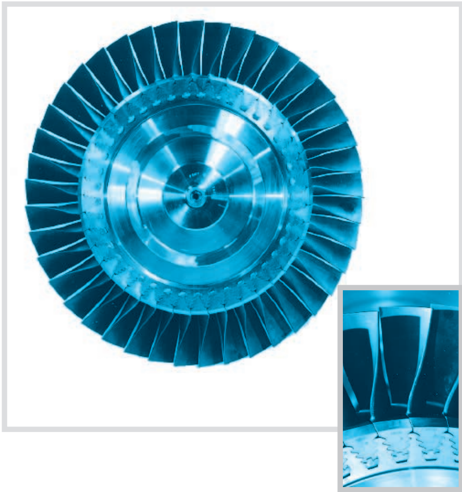
The highly stressed, one-part compressor wheel consists of a forged and milled-to-shape aluminum block that withstands the high circumferential velocities of up to 560 m/s. It builds up the necessary charge pressure and supplies the engine with the necessary amount of air. The compressor wheel and the turbine rotor are both seated together on the rotor shaft.

A special fastening method enables simple mounting and disassembly.

The rotor shaft runs in plain bearings which enable precise centering of the rotor shaft. These bearings have ideal properties under extreme high axial and radial forces and ensure long service life.
They have a high damping effect due to the hydraulic oil film, and are also insensitive to vibrations and imbalance. In order to ensure quiet running even at high speeds, both radial bearings are designed as floating bearings.



Turbine Rotor and Turbine Blades



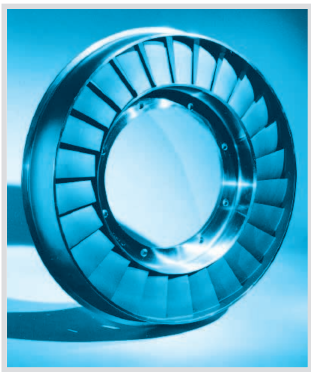
The forged turbine disk consists of a high-tensile, heat resistant alloy and is connected with the rotor shaft by means of friction welding. The blades are precision forged and consist of a nimonic alloy.

They are fastened to the turbine disk by means of fir-tree foot connections. FEM calculation and extensive operational testing with load measuring at the burner rig ensure highest reliability.

The form of the blades is constructively designed in such a manner that it was possible to omit the otherwise usual damping wire in the blade ring both for two-stroke as well as for four-stroke engines.

The turbine blades are very well accessible for inspection and cleaning.

Nozzle Ring



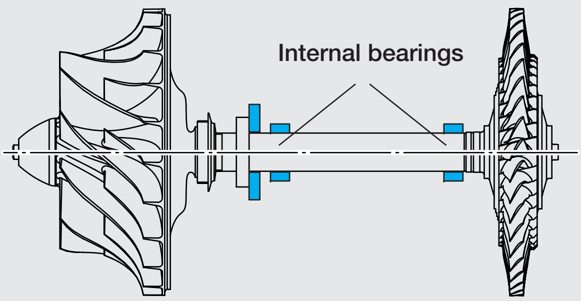
The cast nozzle ring with profiled blades largely contributes to the excellent efficiency of the turbine of the TCA Series. As a result of the improved flow in the nozzle ring, the vibration actuation of the rotor blades is reduced.

At the same time the stability in comparison to nozzle rings formed out of sheet metal is considerably improved, especially of those subject to heavy stress from cleaning granulates.

Internal Bearings

The higher plain-bearing clearances of the rotor shaft, when compared to exhaust gas turbochargers of the previous design, ensure exact alignment of the rotor; critical rotor vibrations occur only beyond the operating speeds.

For almost 70 years MAN Diesel has been using plain bearings in turbochargers with great success. The huge experience resulting has been turned into a bearing concept with high longevity.



Bearings TCA

Silencer/Air Filter

Exhaust gas turbochargers for marine engines, as a standard, are equipped with silencers that are surrounded by a filter mat.

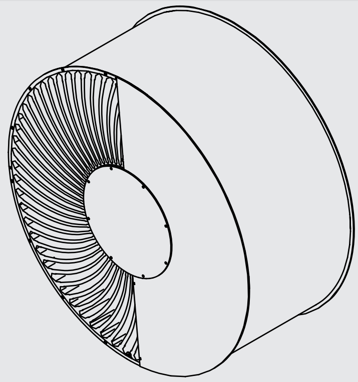
Characteristics:

- High efficiency of the exhaust gas turbocharger due to low pressure loss, especially at high air-flow
- Effective sound level reduction
- Low air-flow velocity at the silencer intake

The silencer is covered by an air filter consisting of soft plastic filter fabric.

Characteristics:

- The effective filtration widely keeps the compressor, diffuser and charge-air cooler free from debris particles
- Easy replacement and installation
- In case filter particles are drawn in, there is no danger of damage to any leading edges of the compressor
- Cleaning of the filter fabric is required only every 250 operating hours (approx.)



Layer design of the silencer

The plastic filter fabric in layer-design has a thickness of 16 mm and is hardened with synthetic resin; the color is white.

It is resistant to temperatures of up to 100 °C, short-term even up to 120 °C. The relative humidity can be 100%. The behavior in fire is self-extinguishing.

The filter mats can be fully regenerated. For this, rinse with warm water from inside to outside, vacuum or blow out with compressed air. If necessary, mild detergents can be added to the water. Avoid heavy mechanical stress such as wringing out or applying a hard water jet.

Technical Data according to ASHRAE (DIN 24 185):

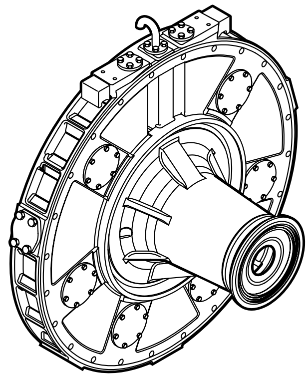
Average separation content 83%
Efficiency .... < 20%
Quality class (filtration class).. EU3
Dust-absorption capacity.....................................520 g/m^3
Pressure loss of filter mats..................................... 200 Pa[1)]

1) 20 water column

Bearing Casing

The bearing casing is manufactured of cast iron with spheroid graphite. It contains the distribution ducts for lube oil and sealing air. The two bearing seats are machined in the same operating step, with the result of exact alignment.

The bearing casing of the TCA turbocharger is equipped with an integrated sealing air pipe. Compressed air is conducted from the back side of the compressor wheel via a duct to the labyrinth shaft seal on the turbine side, with the purpose to effectively avoid oil leakages on the turbine side as well as penetration of exhaust gas into the oil chamber.



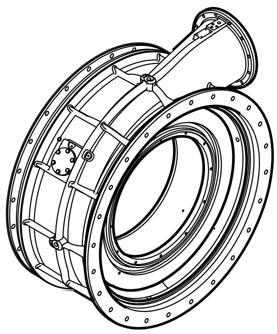
Compressor Casing

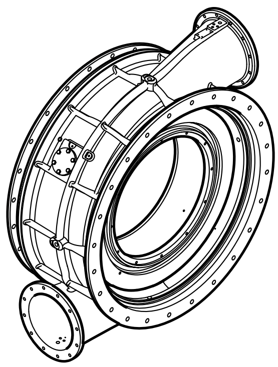
The compressor casing is manufactured of cast iron with spheroid graphite. Single outlet and double outlet are both possible.

The casing position to the bearing casing can be selected from 0° to 360° in steps of 15° (see Table on Page 2-5).

The newly calculated flow cross-sections and the large outlet surfaces ensure effective conversion of the kinetic energy into pressure.

For special applications the compressor casing can be sound-insulated.



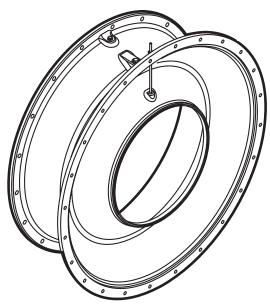


Air Intake Casing

The air intake casing, which is used without air filter during operation, achieves constant distribution of pressure and velocity at the compressor intake due to large-surfaced flow ducts.

The flow duct at the casing outlet is adapted to the respective compressor-wheel size.

The air intake casing can be turned in steps of 15° relative to the bearing casing (see Table on Page 2-5). It is available in the 90° as well as in the axial version.

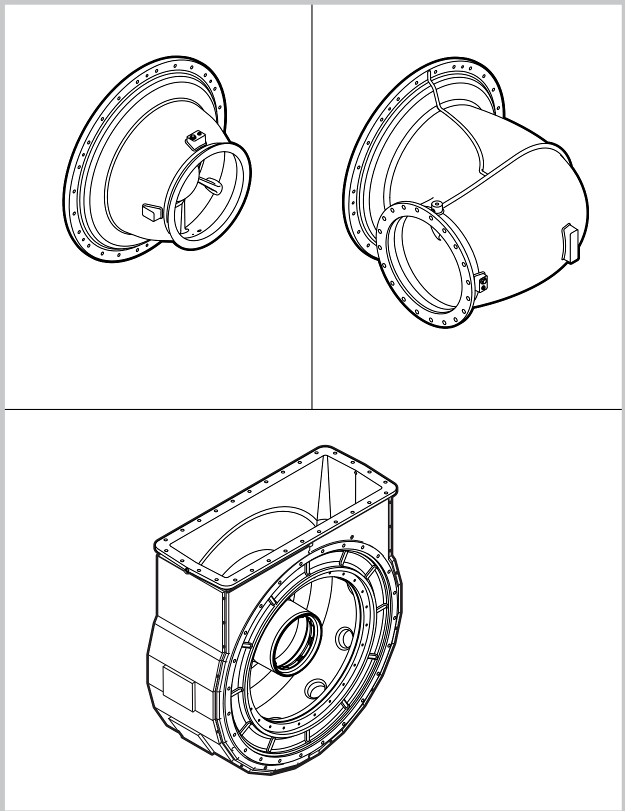


Gas-admission Casing

The gas-admission casing is manufactured of cast iron with spheroid graphite, uncooled and well heat-insulated.

The gas-admission casing can be turned in steps of 15° relative to the bearing casing (see Table on Page 2-5).

The large flow cross-section keeps the loss of flow at a low level.



Gas Outlet Casing

Similar to the gas-admission casing, the gas outlet casing is also manufactured of cast iron with spheroid graphite, uncooled and well heat-insulated. The casing feet are screwed together with the gas outlet casing.

The gas outlet casing can be turned in various positions relative to the bearing casing (see Table on Page 2-5).

The gas outlet casing is equipped with a high-volume and very effective gas outlet diffuser.

Loads on Connections and Flanges

All exhaust gas turbocharger casing flanges, with the exception of the turbine outlet, may be subject only to loads by the effected gas forces, and not to additional exterior forces or torque.

This necessitates the use of compensators directly at the turbine inlet, at the turbine outlet as well as after the compressor.

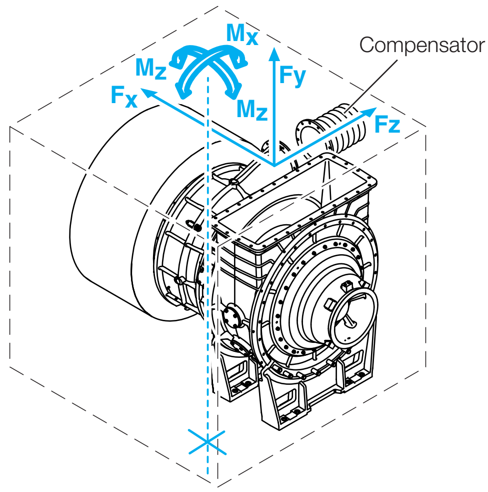
The compensators are to be pre-loaded in such a manner that thermal expansion of the pipes and casing do not effect force or torque in addition to the air or gas forces.

The mentioned parameters for the connections generally refer to single outlet compressor casings as well as for radial and axial air intake casings.

- Forces and torques according to API Standard 617.
- Direction of effect transferred according to MAN Diesel Standard.
- Minimized anticipated loads as far as possible.
- Parameters include forces of masses and compensators.

Connection of the Charge Air Pipes

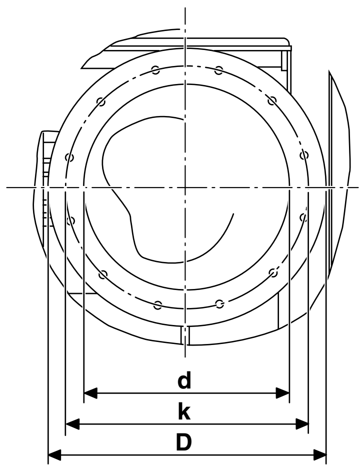
Type	F_x in N	F_y in N	F_z in N	M_x in Nm	M_y in Nm	M_z in Nm
TCA 33	3 700	7 600	7 600	5 800	2 900	2 900
TCA 44	3 900	8 000	8 000	6 000	3 000	3 000
TCA 55	4 200	8 500	8 500	6 500	3 200	3 200
TCA 66	4 600	9 200	9 200	7 000	3 500	3 500
TCA 77	5 000	10 000	10 000	7 600	3 800	3 800
TCA 88	5 400	11 000	11 000	8 300	4 100	4 100
TCA 99	5 600	11 400	11 400	8 600	4 300	4 300



Maximum loads

- For compressor casings with multiple connections the allowable load per connection must be divided by the number of connections.
- Compensator fastened directly to the turbocharger flange
- Flange dimensions according to DIN 2501

Type	D in mm	d in mm	k in mm	Bolts
TCA 33	375	236	335	12 x M12
TCA 44	440	283	395	12 x M16
TCA 55	490	336	445	12 x M16
TCA 66	540	400	495	16 x M16
TCA 77	645	475	600	20 x M20
TCA 88	755	564	705	20 x M20
TCA 99	755	600	705	20 x M20



Compressor casing connection

Connection of the Exhaust Gas Pipe (Engine Side)

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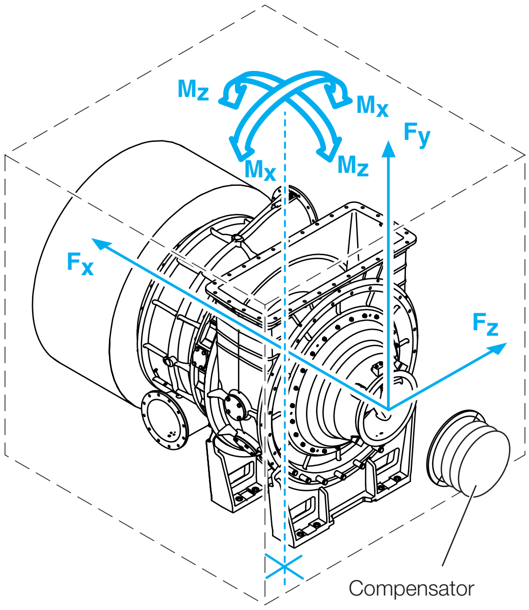
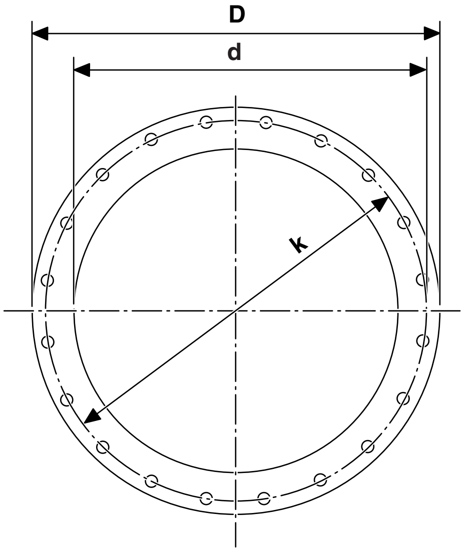


Maximum loads

Type	F_x in N	F_y in N	F_z in N	M_x in Nm	M_y in Nm	M_z in Nm
TCA 33	4 000	8 200	8 200	6 200	3 100	3 100
TCA 44	4 300	8 700	8 700	6 600	3 300	3 300
TCA 55	4 700	9 500	9 500	7 200	3 600	3 600
TCA 66	5 100	10 300	10 300	7 800	3 900	3 900
TCA 77	5 600	11 400	11 400	8 600	4 300	4 300
TCA 88	6 200	12 500	12 500	9 500	4 700	4 700
TCA 99	6 700	13 600	13 600	10 300	5 100	5 100

- Forces also apply for 90° gas-admission casings
- Compensator fastened directly to the turbocharger flange

- Flange dimensions according to DIN 2501

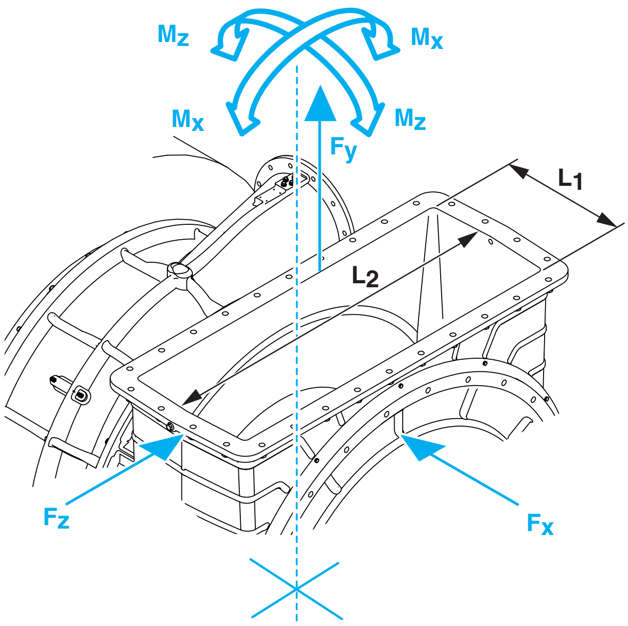


Connection of gas-admission casing (90°)

Type	D in mm	d in mm	k in mm	Bolts
TCA 33	440	300	395	12 x M16
TCA 44	490	350	445	12 x M16
TCA 55	540	425	495	16 x M16
TCA 66	645	500	600	20 x M16
TCA 77	755	600	705	20 x M20
TCA 88	860	700	810	24 x M20
TCA 99	975	800	920	24 x M24

Connection of the Exhaust Gas Pipe (System Side)

Type	F_x in N	F_y in N	F_z in N	M_x in Nm	M_z in Nm
TCA 33	3 900	7 900	7 900	6 000	3 000
TCA 44	4 200	8 500	8 500	6 400	3 200
TCA 55	4 500	9 100	9 100	6 900	3 400
TCA 66	4 900	9 900	9 900	7 500	3 700
TCA 77	5 400	10 900	10 900	8 200	4 100
TCA 88	5 900	12 000	12 000	9 100	4 500
TCA 99	6 300	12 700	12 700	9 600	4 800

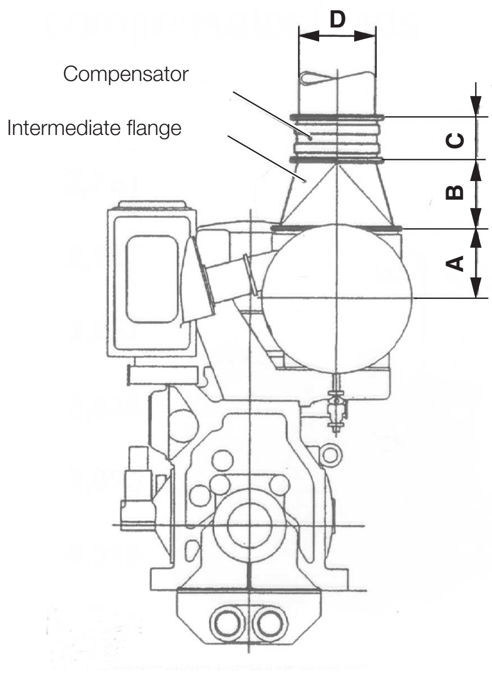


Maximum loads

- Compensator fastened directly to the intermediate flange

Type	A in mm	B in mm	C in mm	D in mm	L_1 in mm	L_2 in mm
TCA 33	480	425	1)	600	273	758
TCA 44	570	495	1)	700	328	910
TCA 55	680	635	1)	900	390	1 080
TCA 66	810	705	1)	1 000	463	1 283
TCA 77	960	850	1)	1 200	550	1 524
TCA 88	1 140	990	1)	1 400	653	1 810
TCA 99	1 250	1 130	1)	1 600	717	1 985

1) Length depends on whether or not the machine installation is fixed or elastic.



Connection of gas-outlet casing

Allowable Inclinations

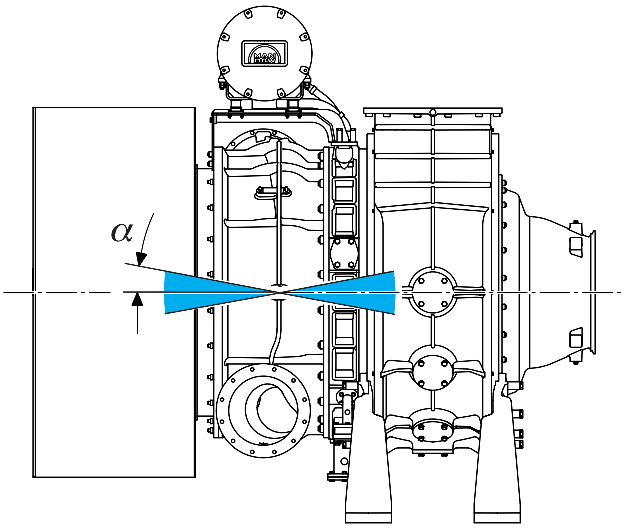
The exhaust gas turbochargers of the TCA Series require horizontal assembly with respect to the axis of the running equipment.

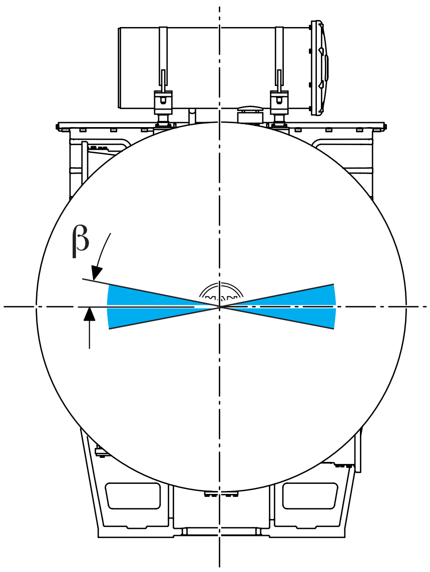
For operation in ships, however, where the installation position is crosswise to the longitudinal axis, inclination angles occur that can influence the operating ability of the exhaust gas turbocharger.

The following inclination angles can be handled by the exhaust gas turbocharger without problems.

With the installation position in longitudinal direction of the ship, these limit values are not reached even under unfavorable exterior conditions.

For certain individual cases, larger inclination angles are also possible. When required, please contact MAN Diesel SE in Augsburg.





Inclination	Continuous	Short-term
α in °	± 15	± 22.5
β in °	± 15	± 22.5

Allowable Vibration Limit Values

During engine operation, the exhaust gas turbocharger is subject to stress through vibrations that are actuated by the engine (**A**) and the exhaust gas turbocharger (**B**) itself. The excitations starting from the engine lie within the low-frequency range. The resulting vibrations of the turbocharger structure stress the possibly mounted silencer and connecting elements between casing parts and turbocharger feet. The bearing load resulting from the engine excitation is negligible, as the rotors of the MAN Diesel exhaust gas turbocharger run in plain bearings.

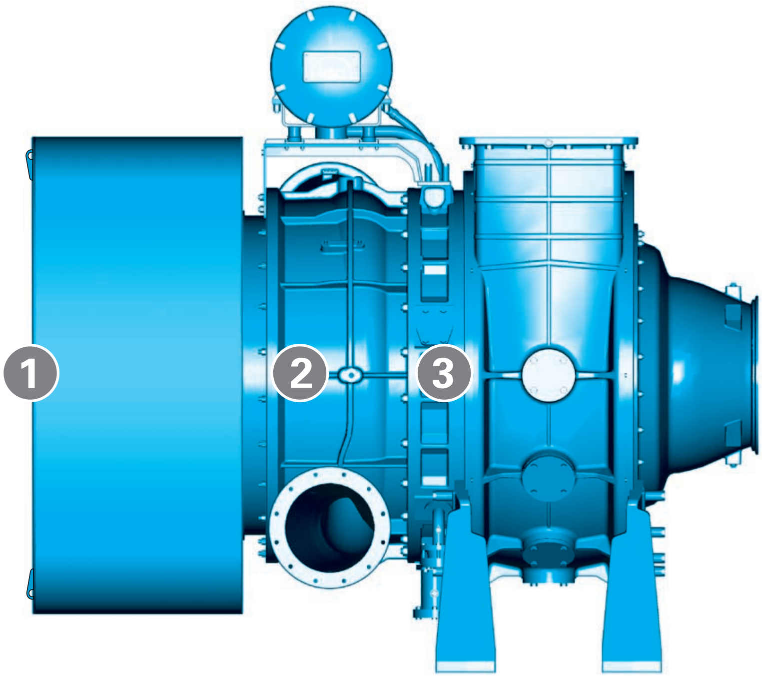
Vibrations actuated from the exhaust gas turbocharger itself are generated by forces of imbalance that are transmitted via the bearing onto the casings. The relevant frequency is in the high-frequency range.
The vibrations resulting from the imbalance forces do not influence the structure of the exhaust gas turbocharger casing, but serve as an indicator for the balance condition of the rotor and thus for the running behavior.

Imbalances occurring during operation can be caused through irregular dirt deposits, damaged vanes of the compressor and/or turbine wheel or residual imbalance.

When erratic running of the turbocharger is observed during operation, the condition can be improved in most cases by cleaning of the compressor (see Page 6-1) and the turbine (see Page 6-1 ff.).

If the running behavior is still not satisfactory after repeated cleaning, the rotor is to be inspected and a balance check is to be carried out.

The measuring points, as well as the maximal allowable vibrational speeds and accelerations for both excitation types mentioned are listed in the following:



(1) Measurement on the silencer front plate, horizontal, vertical and axial
(2) Measurement on the flange of the compressor casing, horizontal, vertical and axial
(3) Measurement on the flange of the bearing casing, radial

Measuring points for vibration speed and vibration acceleration

A: Frequency range, excitation degree caused through engine

- For turbochargers with radial silencer: Measuring point ❶

Type	Frequency Range in Hz	Allowable vibrational speed in mm/s effective, cumulative value 1)	Frequency Range in Hz	Allowable vibrational acceleration effective, cumulative value 1)
TCA 55	7 ≤ f < 60	100	60 ≤ f < 160	2g
TCA 66	7 ≤ f < 60	100	60 ≤ f < 130	2g
TCA 77	7 ≤ f < 60	110	60 ≤ f < 110	2g
TCA 88	7 ≤ f < 60	110	60 ≤ f < 90	2g

1) The vector sum of the measured vibrations in the measurement directions may not exceed the limit values.

- For turbochargers with alternative intake: Measuring point ❷

Type	Frequency Range in Hz	Allowable vibrational speed in mm/s effective, cumulative value 1)	Frequency Range in Hz	Allowable vibrational acceleration effective, cumulative value 1)
TCA 55	7 ≤ f < 60	25	60 ≤ f < 160	1g
TCA 66	7 ≤ f < 60	28	60 ≤ f < 130	1g
TCA 77	7 ≤ f < 50	30	50 ≤ f < 110	1g
TCA 88	7 ≤ f < 50	33	50 ≤ f < 90	1g

1) The vector sum of the measured vibrations in the measurement directions may not exceed the limit values.

B: Frequency range, actuated through the first harmonic oscillation of the rotor speed

- For all turbochargers independent of the compressor admission: Measuring point ❸

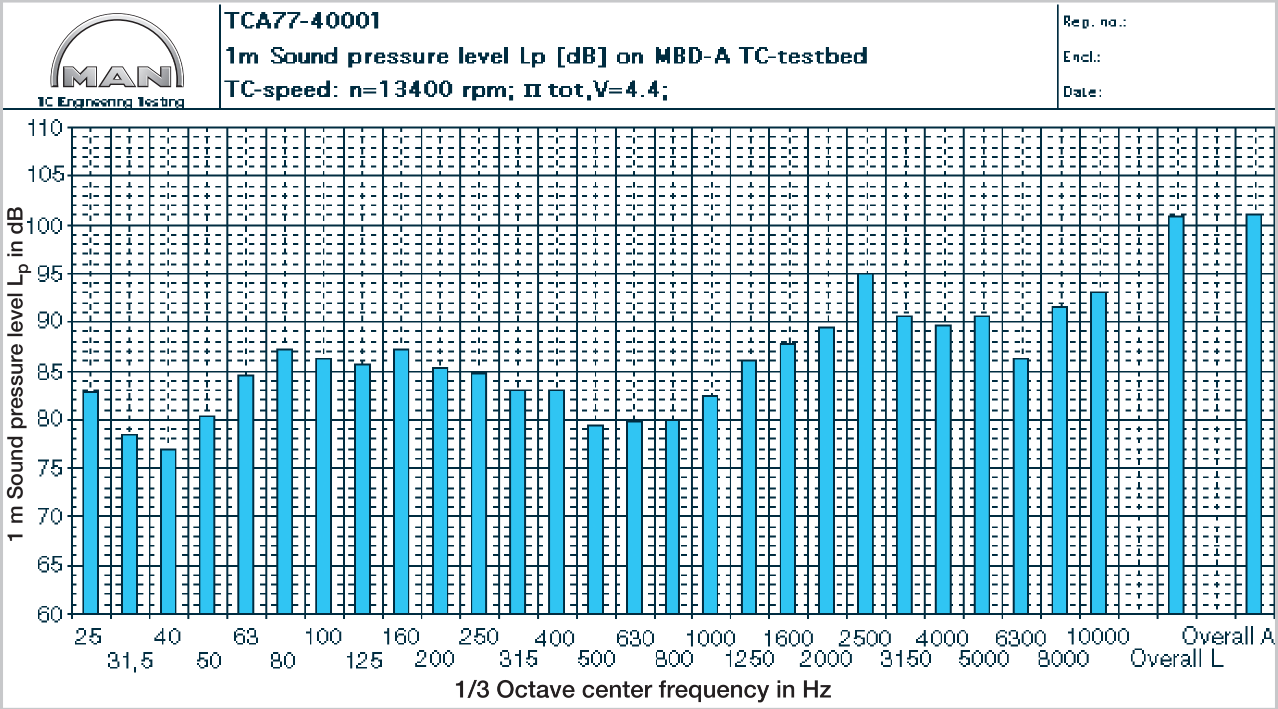
Type	Frequency Range in Hz	Allowable vibrational acceleration, 0-peak, single value
TCA 55	160 ≤ f < 1100	0.8g
TCA 66	130 ≤ f < 900	0.8g
TCA 77	110 ≤ f < 750	0.8g
TCA 88	90 ≤ f < 650	0.8g

Sound Level Diagram

A completely new developed silencer with radial arranged damping elements was designed for the TCA turbocharger. Together with the insulations at the gas outlet casing, gas-admission casing and compressor casing of the turbocharger, sound imission values of below 105 dB (A) can be achieved on the engine.

In the example, the sound level diagram is shown for the TCA 77 exhaust gas turbocharger equipped with radial silencer and air filter. The third octave of the dampened air-intake sound was measured.

Sound pressure level in dB; speed: n = 13 400 rpm.



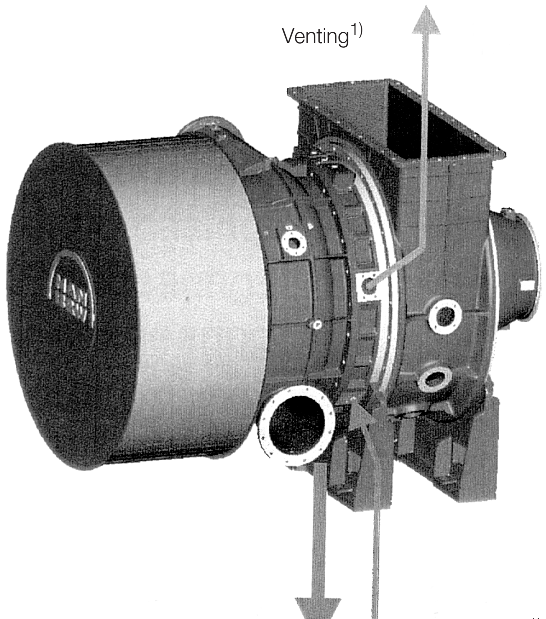
Sound level diagram for TCA 77

Systems

4

Connecting Pipes

To the left and right of the bearing casing, the turbocharger has two connections for lube-oil supply. The connection not needed is closed with a dummy lid. Located somewhat above are two venting connections and below them a connection for oil drainage. For the recommended nominal inner diameter of the piping see the table on the right.



1) Assembly to the right or left side (optional)

Type	Nominal Inner Diameter of Lube-oil Supply Pipe in mm[1)]	Nominal Inner Diameter of Oil Drainage Pipe in mm[1)]	Nominal Inner Diameter of Venting Pipe in mm[1)]
TCA 33	24	51	46
TCA 44	28	60	53
TCA 55	33	69	61
TCA 66	38	80	71
TCA 77	44	92	82
TCA 88	51	107	95
TCA 99	55	115	103

1) Minimum size

Lube Oil System

Lubrication and cooling of the highly stressed bearing bushes and bearings in the exhaust gas turbocharger is effected through a lube oil system which is mainly integrated in the bearing casing.

Function of the Lube Oil System

The lube oil is conducted from the lube oil system of the engine via a supply pipe to the lube oil system of the turbocharger.

A reducing valve (four-stroke engine) or an orifice (two-stroke engine) sets the required lubrication pressure. The lube-oil pressure is controlled behind the non-return valve by means of a pressure controller and a pressure reducer.
The lubricating oil flows through the non-return valve into the turbocharger casing from where it reaches the thrust bearing and the plain bearings via passages in the bearing casing and the bearing body. The lubricating oil flows to the gap between bearing and shaft as well as to the face-sided lubrication point

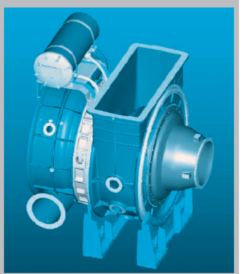
of the thrust bearing via bores in the plain bearings. The lubricating oil leaves the gap and is splashed against the wall of the bearing casing by the rotation of the shaft. The lubricating oil exits the bearing casing through a drain pipe and flows back into the lube oil system of the engine.

Lube Oil Discharge

The drain pipe is to be installed with the maximum possible slope, sufficiently dimensioned and free of resistance and back-ups.

- For ship systems the inclination of the drain pipe must be at least 5° in excess of the largest possible slope of the ship.
- For stationary systems the drain pipe must have an inclination of at least 5°.

Upon request, planning data can also be supplied for self-sufficient lube-oil supply of the exhaust gas turbocharger, independent from the engine lubrication circuit. For more details please directly contact MAN Diesel in Augsburg.



E-Mail:
Turbochargers@de.manbw.com

Shaft Sealing

The bearing casing is sealed with labyrinth sealings on the rotor shaft, both on the turbine and compressor side. The radial labyrinth clearance is dimensioned so that during the first operating phase, the rotating labyrinth tips lightly embed into the softer layer of the cover seal. At higher speeds, the rotor is lightly elevated by means of the lubricating film. The labyrinth tips run freely then. When standing still, the rotor is lowered again. The labyrinth tips embed into the grooves of the cover seal, through which a better sealing effect is achieved during pre and post lubrication. Local run-in grooves at the interior surface area of the sealing covers are thus intentional and not a reason for replacement of the parts.

Flow Rate Lube Oil

The flow rate of the lube oil depends on the viscosity of the oil and the oil temperature.

The following Table applies for SAE 30 at 60° C:

Type	Flow Rate at 2.2 bar in m^3/h	Flow Rate at 1.3 bar in m^3/h	Consumed Energy in kW
TCA 33	3.2	2.9	26
TCA 44	4.4	3.9	32
TCA 55	5.9	5.2	40
TCA 66	7.9	7.0	49
TCA 77	10.6	9.4	60
TCA 88	14.2	12.6	74
TCA 99	16.6	14.7	83

Turbocharger Lube-oil Pressure

The required lube-oil pressure of the turbocharger is adjusted with a pressure reducing valve (four-stroke engine) or an orifice.

The oil pressure is checked via a measuring connection positioned in the lube-oil supply between the non-return valve in front of the entry into the bearing casing.
The lube-oil pressure is to be set in such a manner that a pressure of 1.2 - 2.2 bar is given at this location under full load of the engine with the lube oil at operating temperature.

The following parameters apply for the control of the lube-oil pressure:

- The alarm value is to be set at 1.0 - 1.2 bar for pressure drops of the lube-oil pressure.
- The limit value for load reduction to half load is at 0.8 - 1.0 bar.
- At 0.8 bar, the engine is to be stopped immediately!

When starting the engine and during the warm-up phase of the engine with still cool lube oil, a short-term lube-oil pressure of up to 4 bar is permitted.

For differences in elevation between the pressure-measuring point and the center of the exhaust gas turbocharger, it is imperative to take the value of 0.1 bar per 1 meter of level difference into account.

Example:
If the manometer or the pressure controller is situated three meters below, then the manometer must indicate a value increased by 0.3 bar or the pressure controller must be set 0.3 bar higher than the required operating pressure. The required

lube-oil pressure is adjusted by means of a throttle device in the supply line.

The necessary lube-oil requirement depends on the viscosity of the oil and changes with temperature.

The indication of the active alarm and the reaction through the engine control must occur at the same time. Therefore, the engine control must at least correspond with category 3 according to DIN EN 954-1.

Oil Pressures

Measuring Location	Limit Value
Lubrication-oil pressure during operation (lube oil inlet temperature 40 - 70 °C) in bar	1.2 - 2.2 (6.0) [1)]
Max. lubrication-oil pressure in cold condition in bar	< 4
Pre-lubrication (10 - 30 min.) in bar	0.6 - 2.2 (6.0) [1)]
Post lubrication (10 - 30 min.) in bar	0.2 - 0.6
Settings, Oil Pressure for Alarm	
Alarm in bar	1.0 - 1.2
Direct load reduction of the engine (Slow Down) in bar	0.8 - 1.0
Engine stop (Shut Down) in bar	< 0.8

Pre-lubrication

Before starting the engine, the exhaust gas turbocharger must be pre-lubricated. This is done automatically together with the pre-lubrication of the engine, because as a rule, the lube oil system of the turbocharger is connected to that of the engine. Depending on the engine system, pre-lubrication occurs directly before starting through the continuous pre-lubrication.

Pre-lubrication before starting:

10 - 30 minutes maximum at 0.6 - 2.2 bar (6.0)[1)]

Emergency and Post-lubrication System (Optional)

The TCA emergency and post-lubrication system ensures safe shutting off of the turbocharger in every operating range. It consists of an emergency and post-lubrication tank as well as the internal oil filling. The emergency and post-lubrication tank is mounted above the turbocharger. It ensures the supply of lubricating oil to the turbocharger during the run-down of the turbine rotor as well as the cooling of the bearings upon engine shut-down.

During operation, the non-return valve (at the emergency and post-lubrication tank) is shut. The emergency and post-lubrication tank is filled via a small bypass bore in the valve plate of the non-return valve. As long as the lubrication-oil level is below the overflow, the emergency and post-lubrication tank is pressure-free.

As soon as the lube-oil level reaches the overflow pipe, lube oil flows through the orifice back into the bearing casing. This orifice effects that less lube oil runs off than does run in, until the emergency and post-lubrication tank is filled. This leads to the air in the upper part of the tank being compressed until the pressure in the tank corresponds with the supply pressure.

When the engine is shut down, the pressure in the lube oil system decreases. This has the effect that the non-return valve in the emergency and post-lubrication tank opens and that the non-return valve in the supply pipe shuts. At first the lube oil flows out of the emergency and post-lubrication tank under pressure, back into the turbocharger to the bearing locations. As soon as the lube-oil level falls below the overflow, the emergency and post-lubrication tank is pressure-free again. The lube oil is now transported to the bearing locations via gravity. Once the height of the supply/drain pipe is reached, the remaining volume in the tank flows through a small bore in the supply/drain pipe close to the bottom passage. The size of the bore is dimensioned in such a manner that by means of the geodetic pressure, only the bearing on the turbine side is subject to post lubrication.

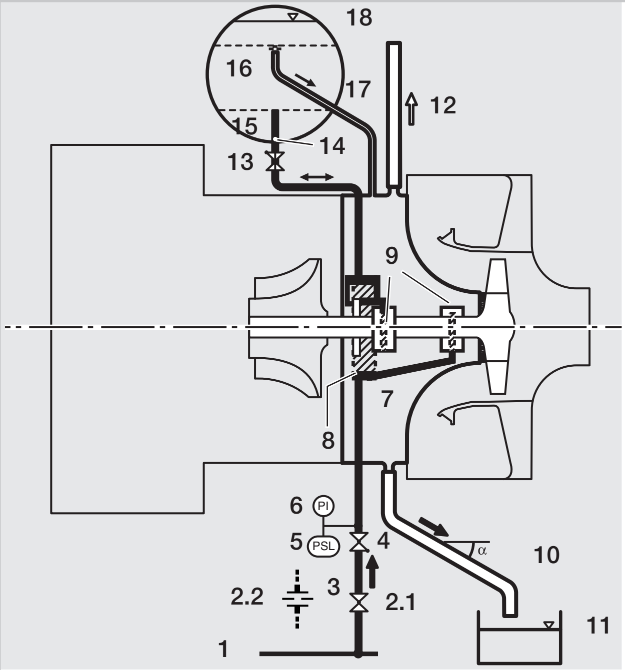
The post lubrication via the emergency and post-lubrication tank occurs automatically. Under the following criteria, it is possible to do without the emergency and post-lubrication system on engine systems with the lube oil pump attached:

- When "Black-Ship" function tests are continuously carried out at only 20% engine load or when these are limited to a maximum of 20 minutes with the engine load greater than 20%.
- When post-lubrication of the turbocharger is guaranteed on behalf of the system (stand-by pump).

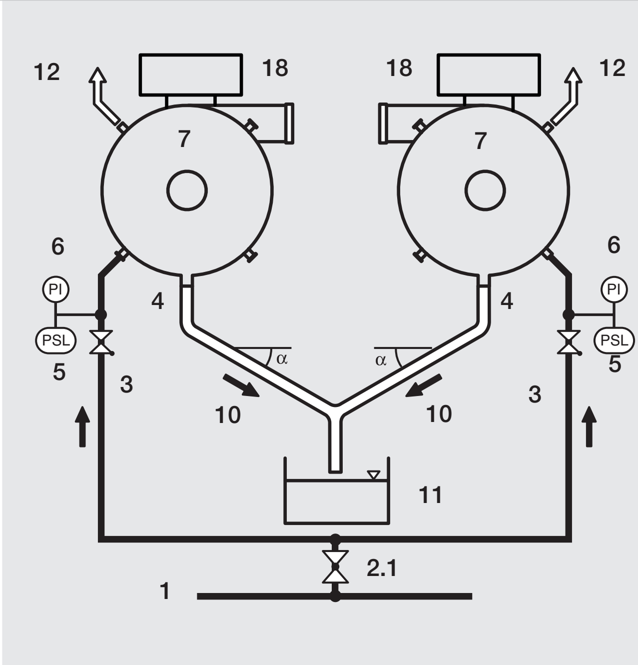
This limitation comes about owing to the necessary cooling of the bearing upon operation.

1) Above 2.2 bar with orifice matched to the engine pressure. Provide for pressure measurement of alarm, slow-down and shutdown behind the orifice (see diagram on Page 4-4)

Lube Oil System on the Turbocharger



Lubricating-oil diagram



Connection of multiple turbochargers

1	Supply pipe (engine) *
2.1	Pressure reduction valve (four-stroke engine)*
2.2	Orifice (two-stroke engine) *
3	Turbocharger supply pipe *
4	Non-return valve
5	Pressure monitor *
6	Manometer *
7	Bearing casing
8	Thrust bearing
9	Bearing bush
10	Drain pipe *
11	Service tank or crankcase *
12	Venting pipe *
13	Non-return valve with bypass
14	Bore
15	Supply/drain pipe
16	Orifice
17	Overflow pipe
18	Emergency and post-lubrication system (optional)

* Delivery scope of engine manufacturer

Note

The lube oil drainage (10) must be installed with an incline that is to be calculated as follows:

Incline α > max. system inclination: +5°

Filtration of Lube Oil

Additional lubrication-oil filters are not necessary; the nowadays usual filtration for heavy fuel oil operation is sufficient, as far as the pass-through size of particles ≤ 0.05 mm. Furthermore, it is assumed that the engine lube oil is continuously maintained by separation and is not enriched with residual matter exceeding 0.02 mm and water.

Before the first starting of operation or after extended maintenance, the pipes between engine filter and exhaust gas turbocharger are to be thoroughly pickled, cleaned and flushed. Clean oil increases the service life of the plain bearings.

Taking an Oil Sample

In order to receive a representative oil sample, the following requirements are to be met:

- Take oil sample only while the engine is running
- Take oil sample in front of the exhaust gas turbocharger and always at the same location
- Fill sample bottle only to 90%
- Provide for a special sample removal cock

Evaluation of the Lubricating Oil Condition

For exhaust gas turbochargers that are supplied with oil via the engine lube oil circuit, the assessment criteria of the engine manufacturer primarily apply for the evaluation of the lube oil condition.

For exhaust gas turbochargers with their own lube oil system, regular checks of the lube oil condition are to be carried through. For routine inspections of the lube oil condition, the parameters in the Table below are sufficient.

The mentioned limit values are empirical field values with orientation of the engine requirements toward the lubricating oil. In order to reach long storage service life, these limit values must not be exceeded.

A binding statement on the further usability of the oil can only be derived from a full analysis where the values are to be determined according to standardized testing methods.

Oil Parameters for Routine Inspections	Limit Value
Viscosity	± one viscosity class
Water content in Wt.%	< 0.2 (short-term to 0.5)
Total contamination in Wt.%	≤ 2.0

Changing the Oil

An oil change is required when the chemical/physical parameters of the oil filling have changed in such a manner that the lubricating, cleaning and neutralizing properties are no longer sufficient. In this, the limit values mentioned in the Table as well as a drop test can serve only as a reference.

Sealing Air Systems

The sealing air prevents the penetration of hot exhaust gas into the bearing casing and lube oil from seeping into the turbine (oil coke). It also helps to reduce undesired thrust on the axial bearing disc.

Sealing Air

The sealing air system is fully integrated in the bearing casing. A part of the air compressed by the compressor wheel is diverted and flows out of the compressor casing into a ring duct in the bearing casing. From there the air is led into the sealing air pipe, whereby an orifice reduces the pressure to the required sealing air pressure. The air is led to a ring duct on the turbine side of the bearing casing. There the sealing air emerges between shaft and turbine labyrinth:

- A small amount of the sealing air flows back into the bearing casing via the labyrinth rings and thus holds back the lubricating oil.
- The other part of the sealing air is led past the turbine disk into the gas outlet casing.

The sealing air pressure is factory set via the orifice and must not be controlled or readjusted by the user.

With four-stroke engines, a vacuum can develop on the compressor side at reduced partial load (suction operation). In this case a compensation pipe between sealing air pipe and ambient air prevents lubricating oil and exhaust gas from being drawn into the compressor casing.

A non-return valve blocks the compensation pipe during regular operation. In case of a vacuum in the sealing air system, the non-return valve opens and outside air is drawn in through the compensation pipe.

External Sealing Air

For special applications such as sequential supercharging, external sealing air can optionally be connected to the TCA turbocharger.

For this a compressed-air supply line with orifice is connected to the non-return valve of the compensation pipe instead of the pipe bend.
The entry pressure in the turbocharger is 1.3 - 1.5 bar.

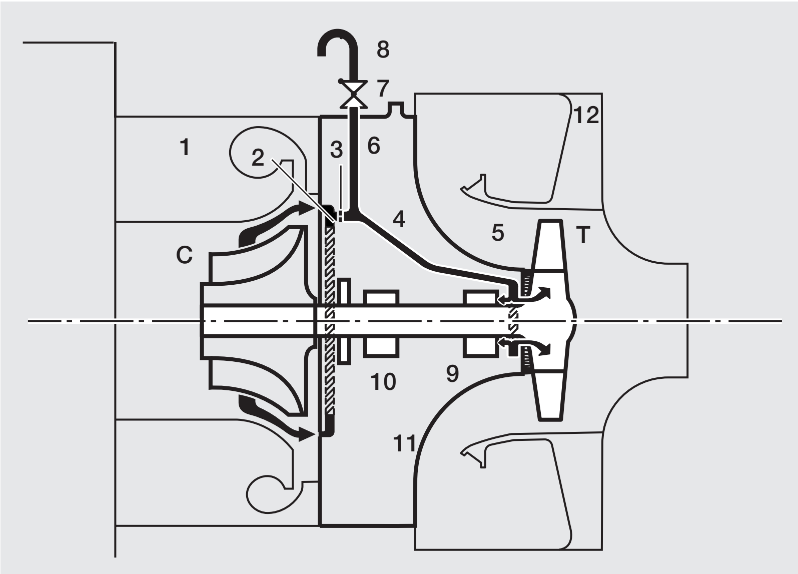
MAN Diesel recommends the sealing air pipes to be dimensioned as follows:

Type	Nominal Inner Diameter of External Sealing Air Pipe Air Pressure 1.5 bar in mm
TCA 33	17
TCA 44	18.5
TCA 55	20
TCA 66	21
TCA 77	24
TCA 88	27
TCA 99	—

Venting

Due to constructive measures, this turbocharger does not require a separate venting box. Lubricating oil and air are separated from each other within the bearing casing. The connection for the venting pipe is attached directly at the bearing casing.
The proportion between the venting mass flow rate and the mass flow rate put through the compressor is 0.2% max. It is recommended to dimension the venting pipe according to the Table on Page 4-1.

Diagram of Sealing Air and External Sealing Air



1 Compressor casing
2 Ring duct, compressor-side
3 Orifice
4 Sealing air pipe
5 Ring duct, turbine-side
6 Compensation pipe
7 Non-return valve
8 Pipe bend
9 Bearing bush
10 Locating bearing
11 Bearing casing
12 Gas outlet casing

C Compressor wheel
T Turbine wheel

Sealing-air Diagram

5 Quality Requirements

Fuels

The quality of the fuel with which the engine is operated affects the composition of the exhaust gas that flows through the turbocharger. Impurities in the fuel can lead to residue in the exhaust gas which can effect the turbocharger in an abrasive or corrosive manner.

Marine Diesel Oil (MDO)

Marine Diesel Oil (MDO) is also known as diesel fuel oil, diesel oil, bunker diesel oil or marine diesel fuel.

MDO is offered exclusively for shipping as a heavy distillate (ISO-F-DMB) or as a mixture of distillate and low amounts of residual oil (ISO-F-DMC). The term “blended MDO” is common for the dark brown to black colored mixture. MDO is produced from crude oil and must be free of organic acids.

The usability of the fuel depends on the design of the engine and the cleaning device as well as if the characteristics mentioned below, which are based on the condition at the time of supply, are observed.

The characteristics determined were based on ISO 8217-1996 and CIMAC-2003 specifications. The characteristics refer to the mentioned testing methods.

	Testing Method	Parameter	
ISO-F specification		DMB	DMC
Density at 15°C in kg/m^3	ISO 3675	0.900	0.920
Kinematical viscosity at 40°C in mm^2/s=cSt	ISO 3104	< 11	< 14
Pour Point Winter quality in °C Summer quality in °C	ISO 3016	 < 0 < 6	 < 0 < 6
Flash point (Pensky Martens) in °C	ISO 2719	> 60	> 60
Total sediment content in Wt.%	ISO CD 10307	0.10	0.10
Water content in Vol.%	ISO 3733	< 0.3	< 0.3
Sulfur content in Wt.%	ISO 8754	< 2.0	< 2.0

	Testing Method	Parameter	
ISO-F specification		DMB	DMC
Ash content in Wt.%	ISO 6245	< 0.01	< 0.05
Coke residue (MCR) in Wt.%	ISO CD 10370	> 0.3	< 2.5
Cetane number	ISO 5165	> 40	> 40
Copper strip test	ISO 2160	< 1	< 1
Vanadium content in mg/kg	DIN 51790 T2	0	< 100
Aluminum and silicium content in mg/kg	ISO CD 10478	0	< 25
Visual check		1)	—

1) At room temperatures and with good lighting, the fuel should be clear and appear transparent.

Other specifications	**Parameter**	
British Standard BS MA 100-1987	**Class M2**	**Class M3**
ASTM D 975	2D	4D
ASTM D397	No. 2	No. 4

Mixing fuels can lead to a reduction of quality. This can result in combustion with a higher degree of residuals which can cause heavy contamination of the turbocharger. Extreme contamination can damage the turbocharger.

Therefore the following points are to be observed:

- In loading plants and during transportation, MDO is treated as residual oil. Mixing with, e. g. high-viscous fuel oil or Interfuel remaining in a bunker vessel is possible and can lead to a considerable reduction in quality.
- Different bunker batches of blended MDO (ISO-F DMC) can be incompatible and therefore should not be mixed. For this reason, the respective fuel tank should be emptied to the greatest possible extent before a new batch is filled up.

Ocean water in the fuel aides corrosion in the turbocharger and leads to high-residual combustion. Solid foreign matter increases the mechanical wear in the nozzle ring and the turbine of the turbocharger.

Therefore the following is to be observed:
If blended MDO (ISO-F DMC) is primarily being used, we recommend installing a centrifugal separator in front of the fuel filter. This widely separates solids particles (sand, rust, catalyst residue, catfines) and water so that the cleaning intervals for the filter inserts can also be prolonged.

Operating data:
- Separator admission 65% with reference to the rated throughput capacity
- Separation temperature 40 - 50° C.

Heavy Fuel Oil (HFO)

MAN Diesel turbochargers can be operated on engines that run on crude-oil based heavy fuel oil (HFO), when the engine and the processing system are designed accordingly.

The fuels used must meet the fuel specifications.

The respective limit values that are to be met are listed in the fuel specifications. The limit values that influence the engine operation are to be specified when ordering fuel, e. g. in the bunker or charter clause.

Adding motor oil (waste oil), mineral-oil-foreign materials (e. g. coal oil) and remainders from refining or other processes (e. g. solvent) is prohibited!

This ban is specifically to be pointed out in the fuel order, as it is not yet part of the standard fuel specifications.

Such additions lead to combustion with high residue and increased wear and corrosion on components of the turbocharger. Adding motor oil (waste/old oil) is particularly critical as the lube oil additives cause emulsions to form and keep debris, water and catalyst particles finely distributed in poise. This impedes or avoids the required fuel cleaning.

The heavy fuel oils ISO F-RMK 35/45/55, with a maximum density of 1010 kg/m^3, can be used only when respectively modern separators are available.

Thorough processing of heavy fuel oil is required for trouble-free engine operation.

The following points are to be observed for this:

- Heavily abrasive inorganic, solid foreign substances (catfines, rust, sand) must be separated to the greatest possible extent.

- With an aluminum content >10 mg/kg the abrasive wear in the turbocharger increases heavily.

- Use only separators of the latest generation which are fully effective over a large density range without any adjustment, and separate water with an HFO density of 1.01 g/ml at 15 °C. The cleaning effect is controlled by the separator itself.

- The HFO purification is to be designed in such a manner that the characteristics in Table 5 are reached:

Parameter	Particle Size in µm	Amount
Inorganic solid foreign particles (including catfines)	< 5	< 20 mg/kg 1))
Water	—	< 0.2 Vol.%

1) AlSi content < 15 mg/kg

- With unfavorable vanadium-sodium ratio, the melting temperature of the HFO ash drops to the range of the exhaust valve temperature, which causes hot corrosion. By pre-cleaning the HFO in the settling tank and in the centrifugal separators, the water and thus the water-soluble sodium compounds can be removed to the largest extent.
  With a sodium content exceeding 100 mg/kg, increasing salt deposits in the turbine are to be expected. This jeopardizes the turbocharger operation (among other things by pumping of the turbocharger). When using PTG the sodium content must be limited to 50 mg/kg.
  Under certain conditions hot corrosion can be avoided with a fuel additive that increases the melting temperature of the HFO ash.

- Heavy fuel oils with a high ash content in form of foreign substances, e. g. sand, rust, catfines, increase the mechanical wear in the turbocharger. Heavy fuel oils from catalytic cracking plants can contain catfines. These are generally aluminum silicate which effects high wear in the turbocharger. The determined aluminum content multiplied by 5-8 (depending on catalyst composition) approximately amounts to the content of catalyst material in the HFO.

Fuel Specification Heavy Fuel Oil (HFO)

Fuel Specification							
CIMAC 2003	A30	B30/C10	D80	E/F180	G/H3/K50	—	H/K700
BS MA-100		M4	M5	M7	8/9	M8/—	M9/—
ISO F-RM	A10	B/C10	D15	E/F25	G/H/K35	H/K45	H/K55
System-relevant Parameters							
Viscosity (at 50°C)[1] in mm^2/s = cSt	40	40	80	180	380	500	700
Viscosity (at 100°C)[1] in mm^2/s = cSt	10	10	15	25	35	45	55
Density (at 15°C)[1] in g/ml	0.975	0.981	0.985	0.991/1.010			
Flash point[2] in °C	60	60	60	60	60	60	60
Pour point Summer[1] in °C Winter[2] in °C	 6 0	 24 24	 30 30	 30 30	 30 30	 30 30	 30 30
Engine-relevant Parameters							
Carbon residue[1] (Conradson) in Wt.%	10	10/14	14	15/20	18/22	22	22
Sulfur[1] in Wt.%	3.5	3.5	4	5	5	5	5
Ash[1] in Wt.%	0.10	0.10	0.10	0.15	0.15	0.20	0.20
Vanadium[1] in mg/kg	150	150/300	350	200/500	300/600	600	600
Water[1] in Vol.%	0.5	0.5	0.8	1	1	1	1
Sediment[1] (potential) in Wt.%	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Supplementary Parameters							
Aluminum and silicium[1] in mg/kg	80						
Asphaltenes[1] in Wt.%	2/3 of the carbon residue (Conradson)						
Sodium[1] in mg/kg	Sodium < 1/3 Vanadium, Sodium < 100						
Cetane number of the fluid mixing component: min. 35							
Fuel to be free of mineral-oil-foreign additives such as coal oil or vegetable oil. Free of creosote and lubricating oil (waste oil)							

1) maximum
2) minimum

Lubricating Oil and Additives

Commonly, doped oils (HD oils) are used for gas oil and diesel oil operation (MGO/MDO), whereas semi-alkaline lubricating oils are used for heavy fuel oil operation (HFO).

The base oil must fulfill the following limit values, particularly concerning the aging stability:

Properties	Testing Method	Parameter
Structure	—	Preferably paraffin-based
Behavior in cold, still fluid in °C	ASTM-D2500	-15
Flash point according to Cleveland in °C	ASTM-D92	> 200
Ash content (oxide ash) in Wt.%	ASTM-D482	< 0.02
Carbon residue according to Conradson in c%	ASTM-D189	< 0.05
Aging tendency after 100 h of heating (to 135°C)	MAN aging apparatus	—
n-heptane insoluble in Wt.%	ASTM-D4055 or DIN 51592	< 0.2
Evaporation loss in Wt.%	—	< 2
Spot test (filter paper)	MAN-Test	Visual check[1)]

1) Sample must not show precipitation/parting of resinous and asphaltic aging

Additives must be dissolved in oil and structured in such a manner that as little as possible ash results upon combustion. The ash must have a soft structure. Otherwise, increased formation of residue in the bearing casing of the turbocharger must be taken into account. Hard additive ash enables increased mechanical wear.

Additives may not aid a clogging of the filter inserts, neither in the active or processed condition.

For gas and diesel fuel operation, we recommend HD oils that HD oils that meet the international specifications MIL-L 2104 D or API-CD and have a Base Number (BN) of 12-15 mg KOH/g (NATO-Code No. 0-278) as well as low tendency towards coking or carbonization.

For heavy fuel oil operation, we recommend semi-alkaline lubricating oils that have a Base Number (BN) of 20 - 50 mg KOH/g, depending on the fuel quality.

Properties/Characteristics Lubricating Oil	Parameter
Viscosity	SAE 30/40
Energy eduction in oil in MJ/h	150
Min. lube oil inlet temperature in °C	40
Max. lube oil inlet temperature in °C	70

Intake Air

The state as well as the condition of the intake air has a decisive influence on the performance of the turbocharger. Not only is the atmospheric condition of great importance, but also the degree of solid and gaseous impurities.

Mineral dust particles in the intake air have a wear-increasing effect, whereas chemical/ gaseous ingredients increase corrosion.

For this reason, effective cleaning of the intake air and regular maintenance/cleaning of the silencer air filter mat is required.

Intake Air Characteristics

The particle size in the intake air must not exceed 5 µm after the silencer/air intake casing or ahead of the compressor inlet.

The following maximum concentrations in the intake air may not be exceeded:

Properties/Characteristics	Concentration in mg/Nm^3 [1)]
Dust (sand, cement, CaO, $Al_2 0_3$ etc.)	5
Chlorine	1.5
Sulphur dioxide (SO_2)	1.25
Hydrogensulphide (H_2S)	15

1) Standard cubic meter in Nm^3

When dimensioning the intake air system, pay attention not to exceed a total pressure loss (filter, silencer, pipe) of 20 mbar.

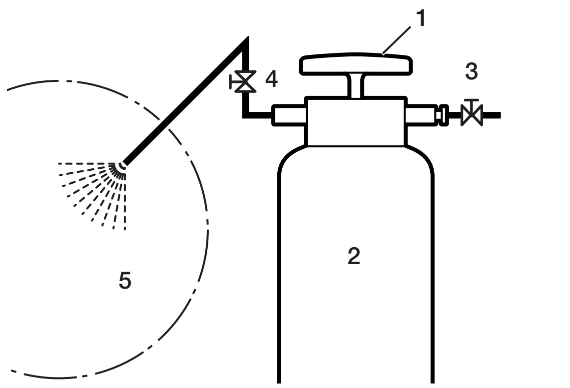
6 Auxiliary Equipment

Compressor Cleaning

During operation, deposits and oily debris films increasingly form on the blades of the compressor wheel and the diffuser. This contamination reduces the efficiency of the compressor.

For this reason, MAN Diesel has developed compressor cleaning systems for all TCA series turbochargers and recommends the use of these.

- Cleaning of the compressor is carried out with water during operation at full load.
- Cleaning is to be performed only with fresh water; do not use ocean water, chemical additives or detergents.
- Blow-in washing water for approx. 30 seconds.
- The cleaning intervals for the compressor should be determined depending on the contamination degree of the respective system. We recommend carrying out the cleaning procedure every 150 to 200 operating hours.



1 Handle
2 Pressure sprayer
3 Overpressure valve
4 Hand valve
5 Turbocharger (compressor)

Diagram "Wet cleaning the compressor"

	Wet Cleaning		Dry Cleaning Turbine
	Turbine	Compressor	
Heavy fuel oil operation	x	x	x
Marine diesel oil/ gas oil operation	x 1)	x	x

1) Depends on fuel ingredients such as vanadium, sodium and nickel.

Turbine Cleaning

From the initial starting of operation on, the exhaust gas turbochargers of engines in heavy oil operation and marine diesel oil/gas oil operation must be cleaned in regular intervals in order to remove combustion residue from the blades of the turbine wheel and the nozzle ring. Otherwise such deposits can impair the operating data or even lead to heavy vibrations of the turbine blades.

The following two cleaning procedures are possible:

- Turbine wet cleaning
- Turbine dry cleaning

Both cleaning procedures can be applied to the same exhaust gas turbocharger, whereby the advantages of both cleaning procedures complement one another.

The wet cleaning of the turbine particularly cleans the nozzle ring, whereas the dry cleaning particularly cleans the turbine wheel (turbine blades).

Note

Observe the cleaning instructions on the instruction plate of the exhaust gas turbocharger and in the operating manual.

Wet Cleaning of the Turbine

Wet cleaning of the turbine is carried out during operation at strongly reduced engine load in order to avoid overstressing of the turbine blades (thermal shock):

Type	Exhaust Temperature ahead of the Turbine in °C	Turbocharger Speed in rpm^{-1}
TCA 33	≤ 320	≤ 15 500
TCA 44	≤ 320	≤ 13 000
TCA 55	≤ 320	≤ 11 000
TCA 66	≤ 320	≤ 9 500
TCA 77	≤ 320	≤ 8 000
TCA 88	≤ 320	≤ 7 000
TCA 99	≤ 320	≤ 5 500

The advantage of wet cleaning as compared to dry cleaning is:

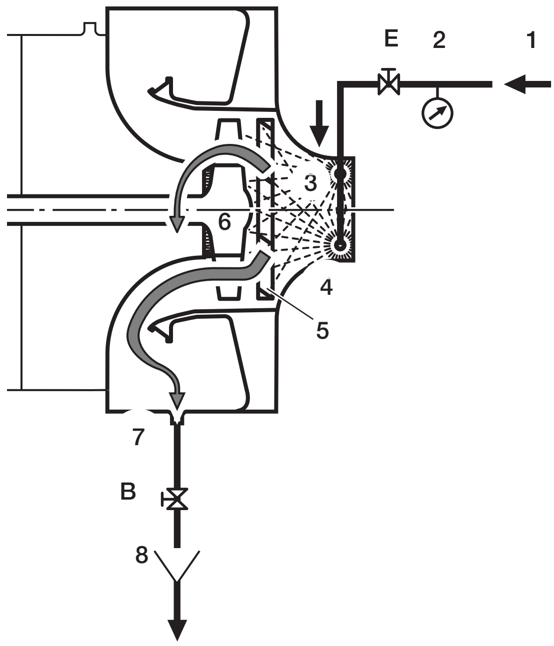
- Better cleaning effect and thus longer cleaning intervals.

The cleaning frequency depends on the type of fuel and on the operating mode; as a general recommendation the cleaning should take place every 250 operating hours.

- Use fresh water without any chemical additives whatsoever.
- The washing duration is 10 to 20 minutes (until clean water comes out of the dirt-water outlet openings).

The wash water flows through the stop cock (water pressure: 2-3 bar) into the gas-admission casing.
The washing nozzles spray the water in front of the turbine. The droplets of the washing water bounce against the nozzle ring and the turbine where they wear off contamination. The washing water collects in the gas-outlet casing and runs through the washing water outlet and the drainage cock. The washing water is conducted via a funnel to a sediment tank and collected there.

The funnel enables the visual inspection of the washing water. The cleaning procedure is completed once the washing water remains clean.



1 Washing water
2 Pressure gauge*
3 Nozzles
4 Gas-admission casing
5 Nozzle ring
6 Turbine wheel
7 Washing water drain*
8 Drain funnel*
B Drainage cock*
E Water stop cock

* Delivery scope of the engine manufacturer

Diagram "Wet Cleaning of the Turbine"

	Quantity of Washing Nozzles, Gas-admission Casing	
Type	90°	axial
TCA 33	1	1
TCA 44	2	2
TCA 55	2	2
TCA 66	4	4
TCA 77	4	4
TCA 88	4	6
TCA 99	4	6

Dry Cleaning of the Turbine

In addition to wet cleaning the turbine, dry cleaning of the turbine can also be performed. Dry cleaning of the turbine is carried out during operation at regular operating load of the engine.

The advantage of dry cleaning as compared to wet cleaning is:

- the dry cleaning can be carried out under full load.

Shorter cleaning intervals must be observed as in regard to wet cleaning of the turbine, otherwise more intense deposits will not be removed.
It is recommended to perform the cleaning with granulates every one to two days.

Depending on the type of funnel, particles of soot can escape during the cleaning procedure. Special consideration should be taken for passenger ships.

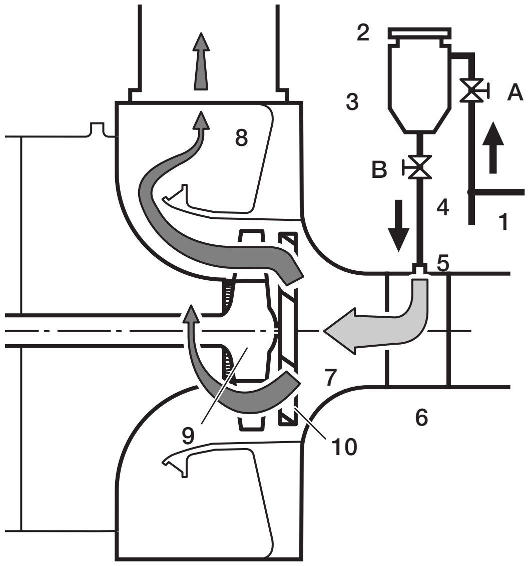
The granulate container is fitted with an opening for filling, a compressed-air supply pipe and a pipe leading to the gas-admission casing. The compressed-air supply pipe and the pipe to the gas-admission casing are each shut with a cock.

The granulate container is filled with cleaning granulates and then shut tight.

Type	Granulate Amount[1)] in l
TCA 33	0.5
TCA 44	0.5
TCA 55	1.0
TCA 66	1.5
TCA 77	2.0
TCA 88	2.5
TCA 99	3.0

1) Granulates consisting of nut shells or activated carbon (soft) with a particle size of 1.0 mm (max. 1.5 mm).

The cock in the compressed-air supply pipe is opened and compressed air flows into the granulate container. Afterwards the cock of the pipe leading to the gas-admission casing is opened. The compressed air blows the granulates out of the granulate container into the gas-admission casing. There, the exhaust flow transports the granulate to the turbine wheel. The granulate particles bounce against the nozzle ring and the turbine wheel, and in this manner remove deposits and contamination. The exhaust flow forwards the granulate and the debris particles out of the system.



1 Compressed air pipe (5-8 bar) *
2 Screw plug
3 Granulate container (filling volume approx. 4 l)
4 Pipe (25x2.0 mm)
5 Connection flange
6 Adapter
7 Gas-admission casing
8 Gas outlet casing
9 Turbine wheel
10 Nozzle ring
A Stop cock (compressed air)
B Stop cock (exhaust gas)

* Delivery scope of the manufacturer

Diagram "Dry Cleaning of the Turbine"

- The granulate container must be fastened at a suitable location and must not be positioned more than 1 m below the connection flange.
- The piping must not be longer than 6 m and must be supported against vibrations. Unhindered through-flow must be ensured.
- Maximum operating temperature of the stop cock (exhaust): ≤ 150 °C.
- The piping should have as few bows as possible with large bend radius.
- The connection flange can be attached either on the intermediate piece of the exhaust pipe or directly on the gas-admission casing.

Connection Sizes for Pipes and Lines

	TCA 33	TCA 44	TCA 55	TCA 66	TCA 77	TCA 88	TCA 99
Compressed-air supply pipe for dry cleaning of turbine in mm/"	Ø 12 x 1.5	Ø 12 x 1.5	Ø 12 x 1.5	G 1/2	G 1/2	G 1/2	G 1/2
Water supply for wet cleaning of turbine in "	G 3/4	G 3/4	G 1	G 1 1/2	G 1 1/2	G 1 1/2	G 1 1/2
Drain connection for wet cleaning of turbine in DN	50	65	65	80	100	125	125

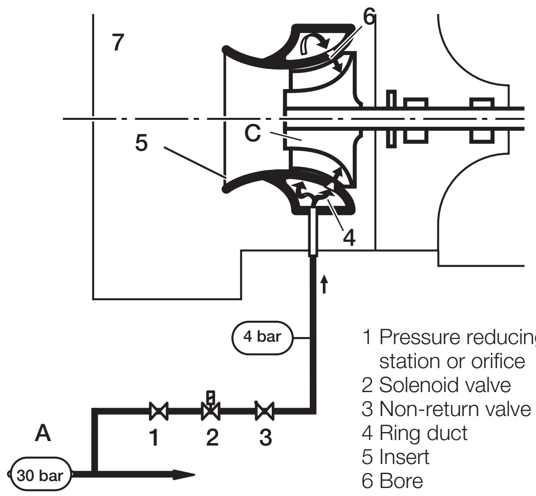
Jet Assist

The “Jet Assist” acceleration system is used when special requirements are made towards swift and possibly soot-free acceleration, and/or towards the load applications of the engine.

In case of sudden load increase, the Jet Assist system accelerates the rotor within an extreme short period by supplying auxiliary compressed air, which is conducted onto the compressor wheel through several nozzles in the compressor insert.

We recommend dimensioning the Jet Assist pipe as follows:

Type	Jet Assist Air Pressure 4 bar in DN			
	4-Stroke Engine		2-Stroke Engine	
	Cross Section of Connection Pipe in mm	Orifice in mm	Cross Section of Connection Pipe in mm	Orifice in mm
TCA 33	37	10.5	39	11.1
TCA 44	44	12.5	46	13.2
TCA 55	51	14.5	54	15.3
TCA 66	61	17.5	64	18.5
TCA 77	67	19.0	70	20.0
TCA 88	81	23.0	84	24.0
TCA 99				



1 Pressure reducing station or orifice
2 Solenoid valve
3 Non-return valve
4 Ring duct
5 Insert
6 Bore
7 Compressor casing

A Starting-air cylinder
C Compressor wheel

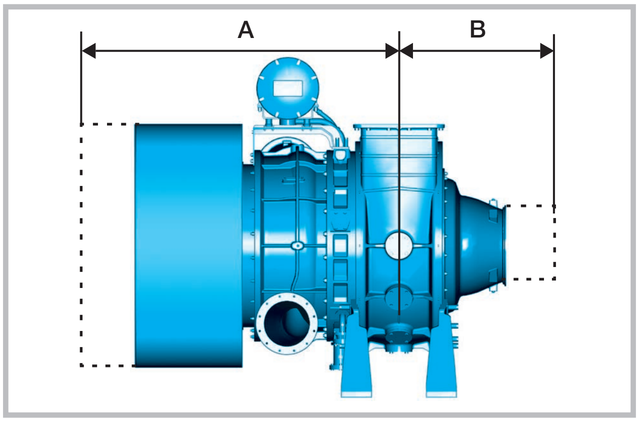
Diagram “Jet-Assist”

7 Engine-room Planning

Provide for hoisting rails with a traversable crane trolley in axial direction above the exhaust gas turbocharger. A lifting tackle with the appropriate minimum carry capacity is inserted into the hoisting rails for lifting of the components so that the specified maintenance can be carried out.

Disassembly Measures and Minimum Carrying Capacity

Disassembly measure A for the radial silencer and disassembly measure B for the turbine rotor, as shown in the graphic, are required to disconnect and remove the silencer and the turbine rotor from the exhaust gas turbocharger:

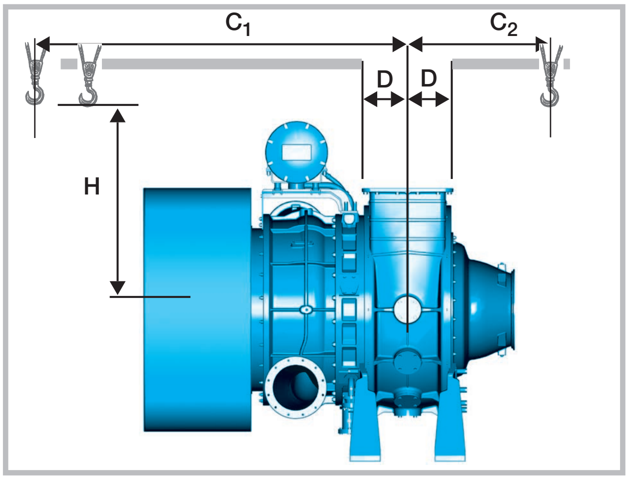


Note

- Disassembly measure B is also the minimum clearance to the next turbocharger.
- The minimum clearance of the silencer to a bulkhead or between-deck should not be less than 100 mm. We recommend planning additional 300 to 400 mm as working space.

Type	A_{min} in mm	B_{min} in mm
TCA 33	1 100	850
TCA 44	1 350	1 050
TCA 55	1 800	1 300
TCA 66	2 050	1 550
TCA 77	2 300	1 800
TCA 88	2 700	2 150
TCA 99	3 000	2 250

On the compressor and turbine side, sufficient space must be provided for between the hoisting rails for the exhaust gas system above the gas outlet casing (the maximal possible measures D may not be exceeded)!



Measures C_1 and C_2 for the two hoisting rails, as well as their minimum carrying capacity (F_{c1} and F_{C2}) are listed in the following Table.

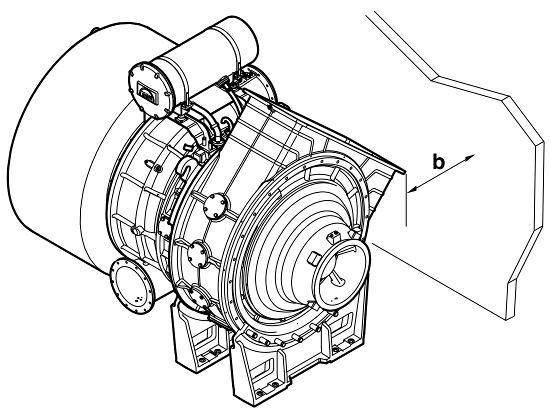
Type	$D_{max.}$ in mm	C_{1min} in mm	F_{C1} in kg	C_{2min} in mm	F_{C2} in kg	H_{min} in mm
TCA 33		1 100	250	850	150	1 000
TCA 44		1 350	450	1 050	200	1 200
TCA 55	260	1 800	700	1 300	350	1 400
TCA 66	260	2 050	1 200	1 550	550	1 600
TCA 77	370	2 300	2 000	1 800	900	1 800
TCA 88	370	2 700	3 000	2 150	1 400	2 000
TCA 99	470	3 000	4 000	2 250	1 800	2 200

Note
Weights of assemblies see Page 2-4.

It must be ensured that the silencer and the gas-admission casing can be removed and placed down either to the bottom, the top or to the side so that the exhaust gas turbocharger can be accessed for additional servicing.

Pipes are not to be installed in these free spaces.

The gas outlet casing can be delivered assembled in various angle positions (also see Table on Page 2-5):



Casing position, gas outlet casing

For these cases, provide for sufficient clearance b between the flange/exhaust gas system and the engine-room walls!

Note
If required, please enquire about the flange clearances relative to the angle position at MAN Diesel in Augsburg.

Exhaust Gas System

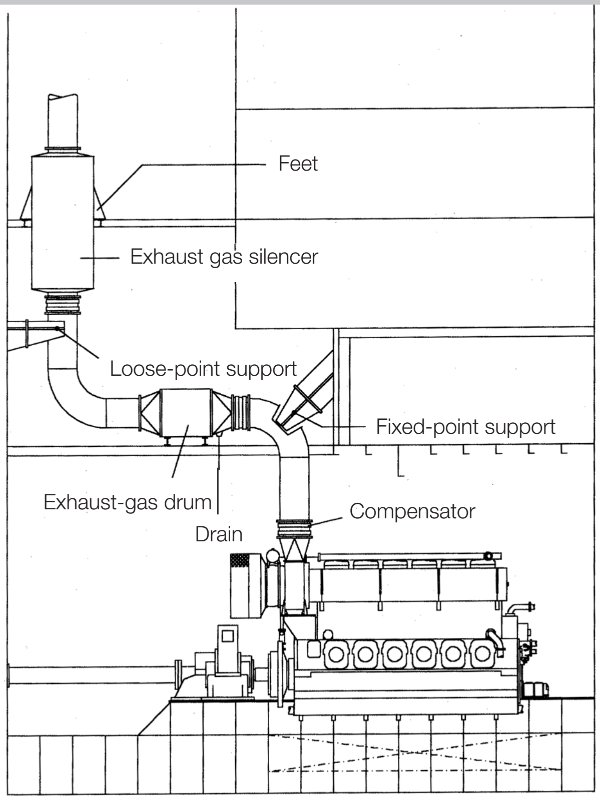
Exhaust-gas resistance has a very large influence on the fuel consumption and the thermal load on the engine.

The pipe diameter depends on:

- the engine output
- the exhaust-gas volume
- the length and guidance of the pipe

Sharp bends result in very high resistance and are therefore to be avoided. Where this is not possible, use pipe bends with blade grids.

Note
The **total resistance** of the exhaust gas system must not exceed **30 mbar**. For this reason, the exhaust gas pipe is to be carried out as short as possible. The **exhaust-gas velocity** in the pipe must not exceed **40 m/s**.



Example for the guidance of an exhaust-gas pipe

Exhaust Gas System - Installation

The following points are to be observed when installing the exhaust gas system:

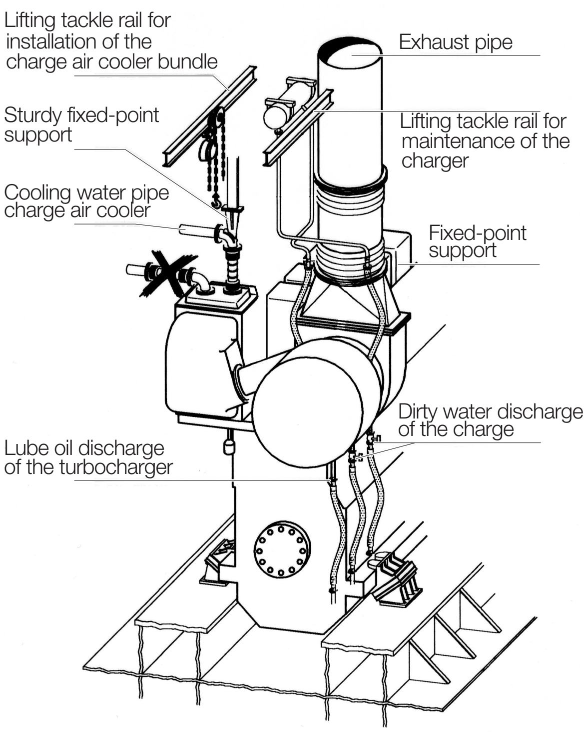
- The exhaust pipes of more than one engine may not be conducted together.
- The exhaust pipes must be able to expand. For this purpose, expansion pieces are installed between the fixed-point supports which are attached at suitable locations. A sturdy fixed-point support is to be provided for directly above the compensator, as far as this is possible, in order to keep forces away from the exhaust-gas turbocharger that result from the weight, the thermal expansion or the sideward axis displacement of the exhaust pipe. To keep the sound transmission in other enclosures of the vessel as low as possible, the exhaust pipes should be fastened flexible or supported with the use of damping elements.
- Continuously opened drainages are to be provided for backflowing condensate and possible drum leakage water.

Installation of Flexible Pipes

Apart from the engine movements caused by rough seas or swell in vertical, axial and transverse direction, the largest motion amplitudes of an elastically supported engine occur in transverse direction while starting and shutting down the engine.

For reasons of improved motion absorption, we therefore recommend the installation of the pipes in axial or vertical direction, and not in transverse direction to the engine.

The loose delivered hoses from NW 32 on have flange connections. All smaller nominal widths receive screw connections. Each hose is delivered together with two counter flanges or, when smaller than DN 32 (rated diameter in mm), with two welded connections.



Installation of flexible hoses

Between the connection on the engine and the hose, a pipe piece that is as short as possible is to be provided for in accordance with the planned run of the pipes.

Directly after the hose, the pipe is to be supported with a fixed-point support positioned above the usual construction. It must be capable of taking up the reaction forces of the hoses and the hydraulic forces of the media.

When the installation is straight, the clearance between the flanges is to be chosen in such a manner that the hose is installed with a sag. During operation, it may not be subject to tensile strain.

For installation with 90° bend, the radii indicated in our drawings are minimum required radii, and must not be fallen below. Hoses may not be installed twisted, which is why the loose flanges on the hoses are designed rotatable.

For screwed connections, the hexagon on the hose is to be counter-held with a wrench when tightening the nut.

Note

Observe the manufacturers instructions.

Turbocharger Connection Dimensions

Two-dimensional drawing with the connection dimensions and three-dimensional CAD models can be supplied upon request.

For more information, please directly contact MAN Diesel in Augsburg. E-mail: Turbochargers@de.manbw.com

Emergency Operation in Case of Failure of an Exhaust Gas Turbocharger

8

Exhaust gas turbochargers are highly stressed turbo machines. As with engines, malfunctions can occur despite careful operations management.

Auxiliary Aides / Fixtures

If damage occurs to a turbocharger that cannot be corrected immediately, emergency operation is possible. The following auxiliary aides / fixtures are available:

- Locking device for blocking of the running equipment.
- Closing cover for shutting of the compressor and turbine back side (operation without rotor).

All auxiliary aides / fixtures are made in such a manner that flow is possible through the air and exhaust gas side of the turbocharger.

For operation on the engine, the following auxiliary aides / fixtures are available:

- Cover screens for the side of the charge air pipes facing away from the exhaust gas turbocharger. The cover screens are supposed to ease the suction operation of the engine (delivery scope of the engine manufacturer).
- Blind flanges for shutting of the partially assembled charge-air bypass pipe (delivery scope of the engine manufacturer).

Emergency Measures

The locking device for blocking of the rotor should be mounted only when removal of the running equipment is not possible, as consequential damages to the turbocharger are possible when the rotor is blocked.

When mounting the locking device, the rotor remains mounted and is blocked with a special tool (scope of supply of the turbocharger) from the compressor side. The intake cross section remains open. For mounting of the locking device, the intake silencer/air intake casing must be removed and installed.

When closing the bearing housing with the closing covers, the rotor must be disassembled first. Afterwards the bearing casing is closed on the turbine and compressor side with two closing covers (scope of supply of the turbocharger). For this, the intake silencer/air intake casing and the gas-admission casing must be removed and installed.

For engines with several turbochargers, the exhaust intake side of the defective turbocharger is additionally separated from the gas flow of the other turbocharger by means of a blind flange.

Achievable Outputs

The following criteria limit the achievable engine load at emergency operation:

- Maximum exhaust gas temperature after cylinders,
- Maximum exhaust gas temperature before turbocharger,
- Smoke number of exhaust gas.

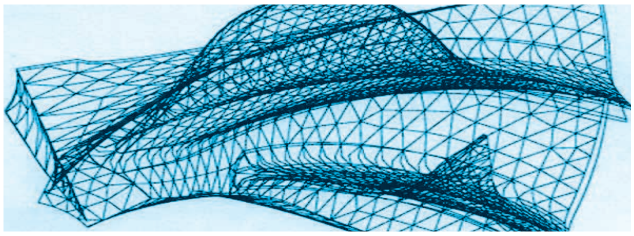
The following table with achievable outputs/speeds only applies as a reference for four-stroke engines:

Type	In-line Engines in %	V-engines in %
Engine operation with variable speed	15	15
Engine operation with constant speed	20	20

Personnel and Time Requirements

Emergency Measure	Qualified Mechanic	Assistant
	Required Time in h	Required Time in h
Locking device	0.6	0.6
Operation without rotor	3.5	3.5

9 Calculations



Layout Calculation

A layout calculation in accordance with the experience of MAN Diesel on the basis of ISO conditions
(298 K/1000 mbar) enables secure engine operation at inlet air temperatures between 278 K and 323 K.

For operation in arctic climate, a blow-off valve is to be provided for after the compressor in order to exclude increased charge pressure and danger of pumping.

For operation in tropical climate, a layout calculation on the basis of ISO conditions is sufficient as far as the resulting higher gas temperatures can be accepted.

The maximum speed of the rotor mentioned on the type plate of the exhaust gas turbocharger is a constant value, despite the respective ambient temperature.

Note

At a given rotor speed, the pressure ratio of the compressor increases with decreasing inlet air temperature and decreases with increasing temperature.

Efficiency

The efficiency is an important criteria for the evaluation of the turbocharger.

The following formula shows how the efficiency of the turbocharger can be calculated. The specific thermal value "c_p" and the isentropic exponent "κ" are temperature-dependent. The isentropic exponent for the exhaust gas "κ_g" is also influenced by the gas composition.

$$\eta_{TC} = \frac{T_1}{T_3} \, \frac{\dot{m}_L}{\dot{m}_g} \, \frac{c_{pL}}{c_{pg}} \left[\frac{\left(p_2/p_1\right)^{\frac{k_L - 1}{k_L}} - 1}{1 - \left(p_4/p_3\right)^{\frac{k_g - 1}{k_g}}} \right]$$

T_1 = Compressor inlet temperature in K
T_3 = Turbine inlet temperature in K
$\dot{m}_L$ = Air mass in kg/s
$\dot{m}_g$ = Gas mass (air and fuel oil in kg/s)
c_{pl} = Specific heat (air in J/kg.K)
c_{pg} = Specific heat (gas in J/kg.K)
p_1 = Air inlet pressure in bar
p_2 = Charge air pressure in bar
p_3 = Turbine inlet pressure in bar
p_4 = Turbine outlet pressure in bar
κ_L = Isentropic exponent (air)
κ_g = Isentropic exponent (gas)
η_{TC} = Turbocharger efficiency
p_2/p_1 = Pressure ratio of compressor
p_3/p_4 = Pressure ratio of turbine

Definition of the Efficiency

MAN Diesel exhaust gas turbochargers are used by various engine manufacturers within and beyond the MAN Diesel Group. Traditionally, various efficiency definitions are customary for exhaust gas turbochargers.

Total (tot - tot)

Total efficiency is one of the most common factors for the thermodynamic characters of an exhaust gas turbocharger. Total pressures directly in front of and after the compressor and in front of turbines as well as total temperatures are to be put into the equation. The flow velocity in the turbine outlet casing is not taken into account as no further stage for the usage of the dynamic pressure is given; as a result, the static exhaust gas turbine outlet pressure is applied and not the total pressure.

Total-static (tot - stat)

This definition is generally preferred for four-stroke engines. The ambient pressure is used and the losses between compressor outlet and inlet are comprehended in the charge air cooler. As only the static compressor-outlet pressure can be used in the engine, and not the dynamic portion, the compressor-outlet pressure is used instead of the total value. As a result, the ambient pressure at the silencer is applied for p_1 and the static pressure after the compressor is applied for p_2.

Please note:

As various losses of the supercharger system are taken into account for the “tot-stat” definition, the efficiency in the “tot-stat” definition is always lower than the “tot-tot” efficiency despite the same thermodynamic capacity of the exhaust gas turbocharger.

Definition for Two-stroke Engines

Basically, this is about a definition of total-static (tot-Stat) as described above. However, the air pressure in the scavenging air pipe plus the cooler-pressure drop are used for p2, while the ambient pressure reduced by the filter losses is used for p_1. For p_3, the pressure in the exhaust manifold is meant.

The efficiencies are calculated with the help of measured operating values. In order to receive a meaningful comparison between exhaust gas turbochargers of varying specifications, sizes, designs and makes, it is always necessary to mention the definition used for the calculation of the efficiency.

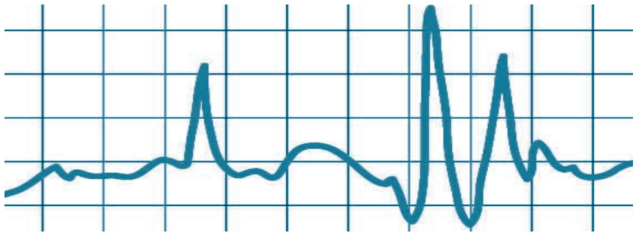
When pressure and temperature before the turbine are not known, then it is not possible to determine the efficiency of exhaust gas turbochargers.

The following Table lists the main differences for the three definitions for calculation of the total efficiency of an exhaust gas turbocharger.

	Definitions for Efficiencies of Exhaust Gas Turbochargers		
	Total (tot-tot)	Total-static (tot-stat) **Four-stroke Engines**	Total- static (tot-stat) **Two-stroke Engines**
Pressure: p_1	Ambient pressure / total air inlet pressure	Ambient pressure / total air inlet pressure	Ambient pressure minus filter losses
Pressure: p_2	Total pressure after compressor	Static pressure after compressor	Air pressure of the scavenging air pipe plus cooler-pressure drop
Pressure: p_3	Total turbine inlet pressure	Total turbine inlet pressure	Pressure in the exhaust gas receiver
Pressure: p_4	Static behind turbine	Static behind turbine	Static behind turbine

10

Speed Measuring, Adjustment, Checking



Speed Measuring

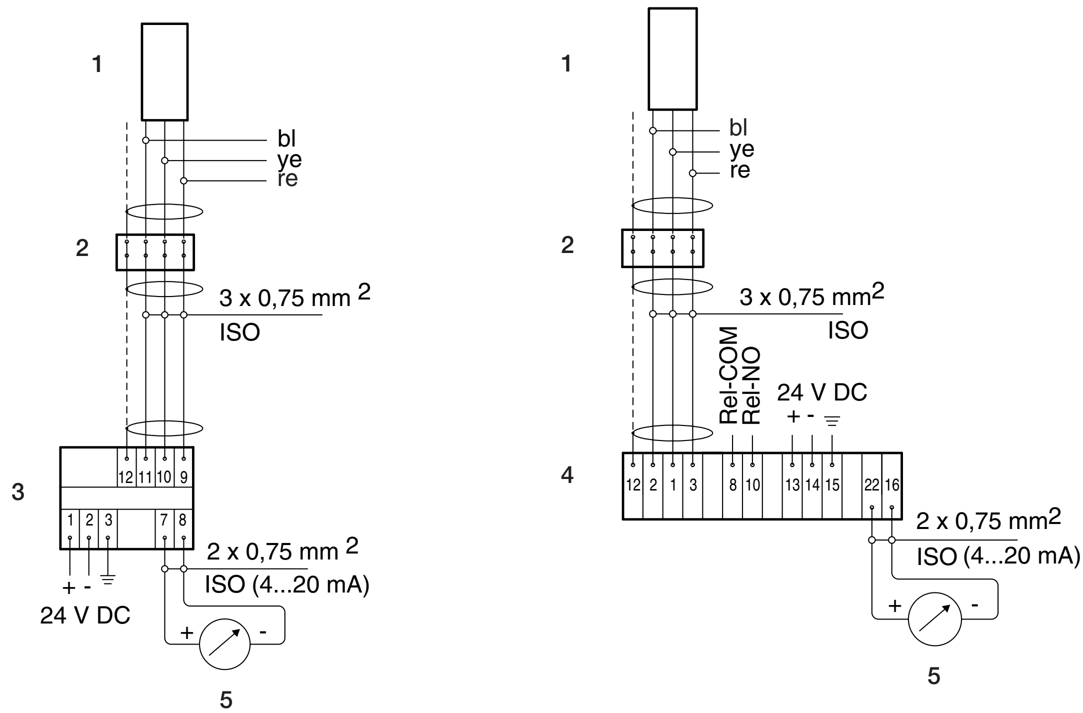
For all exhaust gas turbochargers of the TCA Series, MAN Diesel delivers a speed transmitter for measuring of the rotor speed as standard.

The speed transmitter is arranged radial in the insert piece at the compressor-side end of the rotor and delivers speed impulses. The alternating impulses are conducted via a 3-wire cable to the terminal box on the compressor casing.

From the terminal box, the impulse signal is conducted on to a frequency-current converter or to a digital speed indicator (optional).

The signal can additionally be indicated on a suitable analog measuring instrument. Transmission of the measured values is possible with both types of speed measuring equipment.

MAN Diesel delivers measuring instrument and the transmission system for the measured values on request.



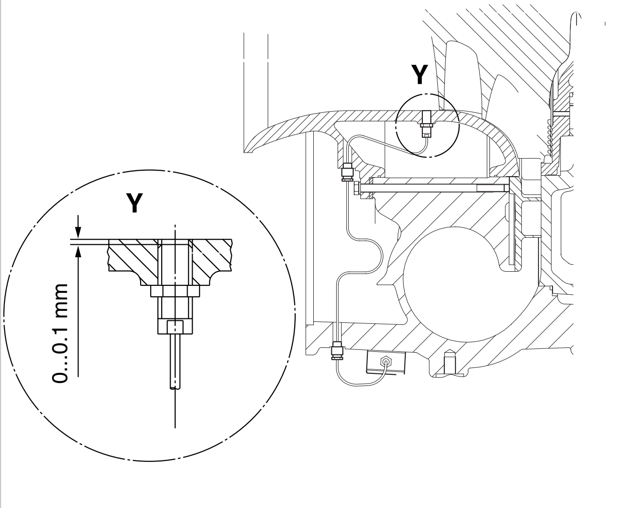
1 Speed transmitter
2 Terminal box
3 Frequency-current converter
4 Digital speed indicator
5 Additional speed indicator (analog) and/or transmission of the measured value

Connection of the speed measuring equipment for the TCA Series

Description of Components

Speed Transmitter:

The insert piece is fitted with a radial located internal thread for fitting of the transmitter. It is arranged in such a manner that the transmitter can be fitted flush against the front edge of the compressor wheel.



Connection of the speed transmitter

The transmitter is screwed in and secured so that its front side is flush with the surface of the insert piece or protrudes inward by 0.1 mm (see section Y), meaning that the radial clearance between the compressor-wheel blades and the face side of the transmitter is not less than the radial compressor gap.

Read-out Units:

The read-out units can be located in the switch cabinet or housed in the operating cabinet. A speed measuring set-up with frequency-current converter is part of the standard MAN Diesel delivery scope. As an alternative, a digital speed indicator or an analog read-out unit can also be connected. Both units require an external 24 V DC supply from which they supply the transmitter with an integrated 12 V transmitter voltage.

- Digital speed indicator
  To ensure correct speed indication, the digital speed indicators must be programmed to the respective amount of compressor wheel main blades before installing (amount of pulses per revolution). When using original MAN Diesel components this adjustment is factory-set.
- Frequency-current converter
  When using a frequency-current converter, the respective amount of compressor wheel main blades (amount of pulses per revolution) and the final range speed must be taken into account upon programming of the unit.

As the speed indication and the compressor wheel must be in tune to each other, the sensing and indication system should be supplied completely through MAN Diesel.

Analog speed indication/detection of measured values:

Both types of speed measuring equipment have a power output (4-20 mA) for connection of an additional analog speed measuring unit and/or the measured value transmission.

Method of Operation:

The HF transmitter with integrated amplifier requires an auxiliary voltage of 4.5 ... 30 V DC, supplied by the speed measuring equipment. It contains a high-frequency oscillator with its oscillator coil located in the transmitter head. The main blades and the compressor-wheel gaps in between effect a varying damping of the oscillating circuit and thus a higher or lower amount of supply current from the oscillator. These current alterations control an electrical, contact-free switching output via a switching amplifier. The amplified signal is additionally processed by the digital speed indicator or frequency-current converter which are specially adapted to the transmitter, and themselves supply the transmitter with the required transmitter voltage.

Measurement of the Air Volume

The measurement of the air volume takes place via calibration of a compressor casing. The comparative measurement is then carried out with the silencer mounted:

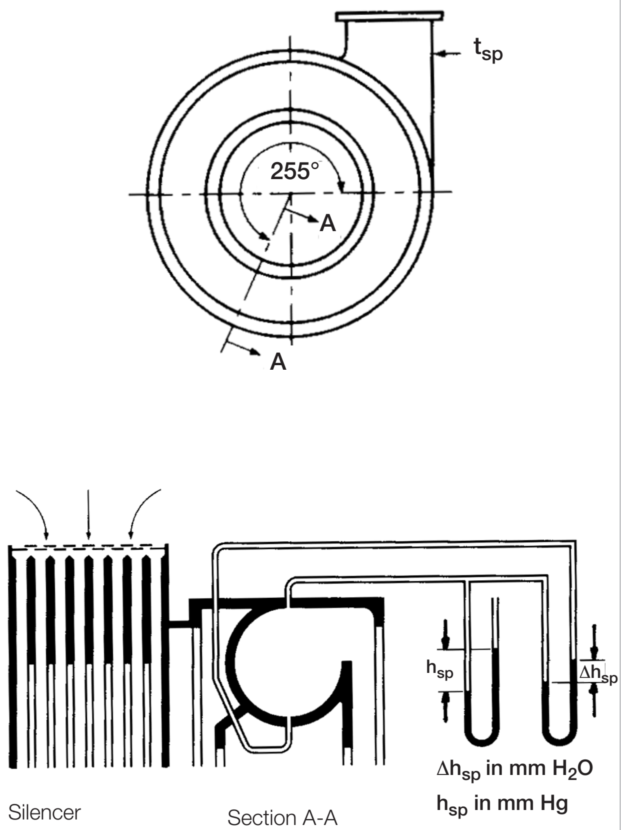
The measuring method is based on the theory of gas flow in manifolds:

The pressure difference between inner and outer wall follows the second power of the flow velocity.

The compressor casing is comparable to a manifold of variable cross-section area. At a certain, through numerous tests determined cross section, the static pressure difference Δh_{sp}, is measured at two opposing wall locations.

As during the testing of the TCA turbocharger both Δh_{sp} as well as the air volume (in the usual manner with orifice) can be measured at the combustion chamber, a calibration curve can be derived.

For the later engine testing, this curve easily enables to determine the air volume with the mounted silencer when Δh_{sp}, the spiral pressure h_{sp} and the outlet temperature t_{sp} are measured:



Spiral pressure h_{sp}, Outlet temperature t_{sp} and Δh_{sp}

This calibration curve is not applicable for other turbochargers, even if for the same size and specification.
The accuracy of this method is approx. ±1%. For diffuser-cross sections other than the calibration curve has been derived for, correction factors are used. In order to ensure reliable measurement, all measuring hoses, extensions, threads, etc. must be absolutely airtight (check by spraying on a soap solution).

Matching Procedure

Each newly specified exhaust gas turbocharger for a new application must be matched so that:

- It is optimized with the best possible flow cross-sections for the operating conditions of the engine,
- A sufficient surge-limit distance is ensured across the complete operating range.

For this purpose, it is customary that different varieties of nozzle rings and diffusers (adaptation components) are delivered on loan for adaptation purposes.

Matching Steps

- Test run the engine with the exhaust gas turbocharger in the "Condition of delivery".
- If the charge-air pressure before cylinder is too low or too high in the design point (as required by the engine manufacturer), the nozzle ring must be exchanged.

  Please note:

  In order to reach a higher air pressure, a smaller nozzle ring must be used. To reach a lower air pressure, a larger nozzle ring must be used.

- At the same time, the surge distance must be checked.

  Please note:

  When the surge distance is less than required, a smaller diffuser must be used (in rare cases even a smaller compressor wheel).
  The part-load range must also be checked for sufficient surge distance.

Checking Surge Stability

"Surging" describes the unstable operation of a compressor when the air mass of an engine operating point becomes too low for the given pressure ratio.

This condition commences when the counterpressure increases too high in comparison with the air mass. In this case, the air flow breaks away and air from the consecutive pipe system flows through the compressor against the feed direction.

After the decrease of pressure, the air begins to flow in the normal direction again until the surge procedure is repeated.

In this process, the compressor wheel is highly stressed so that continuous surging can lead to damage.

The air intake section of the engine system is to be dimensioned in such a manner that pressure blasts of at least 1 bar overpressure can be withstood.

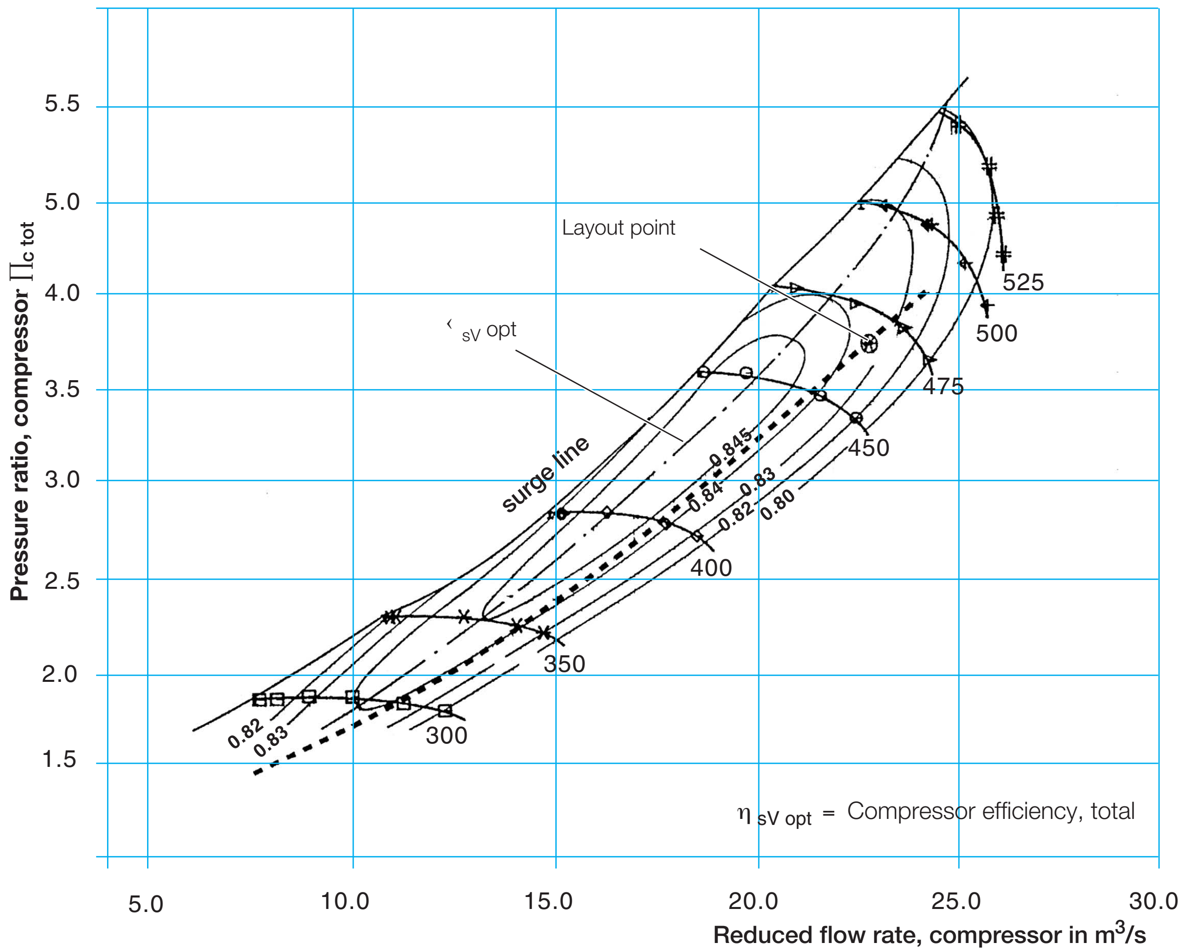
One of the following methods can be applied:

Four-stroke engines:

- Reduce engine speed with constant fuel admission. A speed reduction of at least 15% should be possible without the occurrence of surging.
- Increase the scavenging air temperature at constant power. A temperature increase of at least 50 °C above the air temperature at the compressor inlet should be possible without the occurrence of surging.

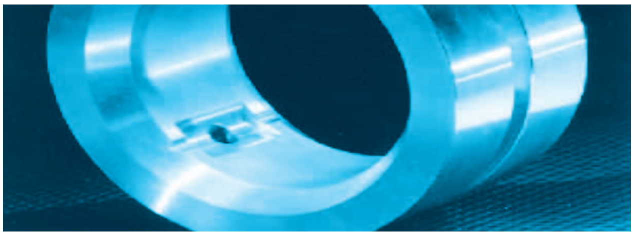
Two-stroke engines:

- Run the engine at 100 % load.
- Reduce the load suddenly to 75 %. If no surging occurs repeat the procedure, but this time reduce the load from 100 % to 50 %. If no surging occurs, the stability above 50 % load is good.
- Run the engine at part load and a charge-air pressure of approx. 0.6 bar overpressure so that the auxiliary ventilators no longer run. Pull the fuel pump of one cylinder suddenly to zero, and repeat this measure with other cylinders. If surging occurs in not more than one case, then the stability is sufficient.



Compressor Characteristics of an Adapted TCA 77

11 Quality Assurance



An integrated quality and environmental management system is established at MAN Diesel which is certified according to ISO 9001 since 1991 and to ISO 14001 since 2001. This affords our customers the confidence that MAN Diesel turbochargers meet customer expectations to complete satisfaction, from development over production to dispatching.

Germanischer Lloyd Certification GmbH

GLC

CERTIFICATE

The Germanischer Lloyd Certification GmbH, 20459 Hamburg, herewith certifies that the company

MAN B&W Diesel AG
Turbocharger Division
Stadtbachstraße 1, 86224 Augsburg, Germany

has established and maintains a Quality Management System relevant for

Development, design, production, installation, servicing and licensing of turbochargers for Diesel engines

Germanischer Lloyd Certification GmbH has audited the company. Evidence was provided that the Quality Management System fulfills the requirements of the following standard:

DIN EN ISO 9001:2000

The validity of this certificate is subject to the company applying and maintaining its Quality Management System in accordance with the standard indicated. This will be monitored by Germanischer Lloyd Certification GmbH.

Initial certification: May 29, 2001
The certificate is valid until June 16, 2006

Hamburg, June 16, 2003

Certificate No. **QS-2306/2 HH**

Germanischer Lloyd GLC Quality Management Systems Certification

Deutscher Akkreditierungs Rat DAR

TGA-ZM-07-91-00

(Dr. Weber)

(K.-P. Schröder)

This certificate is valid only in connection with certificate QS-2306 HH of 16.06.2003

Germanischer Lloyd
Certification

GLC

CERTIFICATE

The Germanischer Lloyd Certification GmbH, 20459 Hamburg,
herewith certifies that the company

MAN B&W

MAN B&W Diesel AG
Stadtbachstraße 1, D-86224 Augsburg

has established and maintains an Environmental Management System relevant for

Development, design, production, installation and servicing of Diesel engines and turbochargers for ships and power plants in Augsburg as well as casting of nodular cast iron and grey cast iron components.

Germanischer Lloyd Certification GmbH has audited the company. Evidence was provided that the Environmental Management System fulfills the requirements of the following standard:

DIN EN ISO 14001
edition: 10/1996

The validity of this certificate is subject to the company applying and maintaining its Environmental Management System in accordance with the standard indicated. This will be monitored by Germanischer Lloyd Certification GmbH.

Validity extended until May 29, 2007

Hamburg, May 25, 2004

GERMANISCHER LLOYD GLC ENVIRONMENTAL MANAGEMENT SYSTEMS CERTIFICATION

Certificate No. **EM-2307 HH**

RvA MGMT. SYS. RvA C 459

(R. Westphal) (J. Rogge)

Description of the Quality Criteria

Standards, Provisions and Regulations

Exhaust gas turbochargers of the MAN Diesel TCA Series meet the regulations of the guideline 98/37/EG (Machine Guideline).

The following national and international standards were applied upon development and production:

- DIN EN 292-1 – Security of Machines; Basic Terms, General Design Guidelines; Part 1: Basic Terminology, Methodology
- DIN EN 292-2- Security of Machines; Basic Terms, General Design Guidelines; Part 2: Technical Guidelines and Specifications
- DIN EN 1050 - Security of Machines; Guidelines for Risk Assessment
- DIN EN 62079 – Creating Manuals; Outline, Contents and Representation
- DIN 7168 – General Tolerances; Length and Angle Measures, Form and Position; not for new constructions
- DIN 6784 – Workpiece Edges
- DIN EN ISO 1302 – Geometric Product Specification (GPS) - Indication of the Surface Condition in the Technical Product Documentation
- Q11.09004-8500 – Turbocharger Quality Guidelines (List of the applied MAN Diesel Works Standards for turbochargers).

Acceptance by International Classification Associations

- Each turbocharger type of the TCA Series receives a type acceptance which includes the following: A drawing check, an examination of the regulation conformity, the type test run at the burner rig with maximum speed and exhaust temperature.
- In addition to this, each individual turbocharger can be ordered and delivered with acceptance and IMO Certificate upon request.
- As the first of its series, the TCA 77 turbocharger is certified by the following international acceptance companies: ABS (American Bureau of Shipping), BV (Bureau Veritas), DNV (Det Norske Veritas Classifikation A.S.), GL (Germanischer Lloyd), LR (Lloyd´s Register of Shipping).

Compressor Wheel

- The die-forged blanks will be crack- and ultrasonic-tested before milling.
- Each compressor-wheel blank carries a test ring on which the strength values will be checked.
- After milling and pre-machining, all compressor wheels will be balanced and spin-tested at speeds far above the maximum allowable operating speeds.
- Measuring of bores and wheel exterior to ensure that all dimensions are still within tolerance.
- Crack testing by penetration method.
- All finishing performed according to specification.
- Checking/measuring of all machined surfaces and diameters.
- Re-balancing of finish-machined compressor wheels.

Turbine Wheel

- Random checks of the blade width in axial and radial direction (20-fold magnification).
- Every blade is checked for cracks prior to machining.
- The fir-tree profile is checked at random with 20-fold magnification.
- Turbine rotors are balanced and spin-tested at speeds far above the maximum allowable operating speeds.
- Measuring of disc and blade-head circular profile to ensure that all measures are within the tolerance range.
- Removal of the blades and repeated crack testing including the rotor shaft.
- Remounting of blades followed by balancing of the turbine rotor.

Service Life Periods

The following data is based on empirical values of MAN Diesel exhaust gas turbochargers that have been manufactured with identical materials and manufacturing procedures.

The mentioned service life periods are reference values that apply under normal operating conditions. They can be considerably reduced due to e.g., insufficient maintenance, frequent “Blackouts” or use of low-quality fuel and lube oil.

	Operating Hours
Plain bearings	up to 50 000
Nozzle ring	up to 40 000
Turbine blades	up to 100 000
Shroud ring	up to 30 000
Compressor wheel	up to 80 000 [1)]
Casing	no limitation

1) Depends on:

- The intake air temperature
- the charge pressure
- the load profile of the engine

and may fall shorter in case of unfavorable values.

Maintenance and Checking

12

When carrying out maintenance and checking work, it is usually sufficient to remove only partial subassemblies of the exhaust gas turbocharger. Only for major overhauls, it can be required to remove the complete exhaust gas turbocharger.

When primary components are repaired or for major overhauls, it is recommended to protocol the condition of the individual assemblies.

Components with traces of wear or damage that particularly influence the strength and smooth running of rotating parts must be replaced against original spare parts or be repaired by an authorized repair shop or the manufacturer.

For shipping, pack and protect components against corrosion so that they remain intact during transportation.

Maintenance

Turbocharger on the Four-stroke Engine

Inspection (during operation) in h	**24**	**150**	**250**	**3 000**	**6 000**	**12 000**
Check turbocharger for abnormal noise and vibrations	X					
Check turbocharger and system pipes for leakages (sealing air, charge air, exhaust gas, lube oil)	X					
Check bolts and piping connections for tight seating[1]				X		

1) Inspection of new or overhauled bolts and piping connections after 250 operating hours required

Maintenance (during operation) in h	**24**	**150**	**250**	**3 000**	**6 000**	**12 000**
Dry cleaning of the turbine	X[1]					
Wet cleaning of the turbine[2]			X[1]			
Clean compressor		X[1]				
Clean air filter[1]			X[1]			

1) or more frequently, as required
2) if given

Maintenance (combined with an engine maintenance) in h	24	150	250	3 000	6 000	12 000
Cleaning the sealing air pipes[1)] in front of the bearing casing				X		
Checking the compressor casing, insert, diffuser and compressor wheel[2)]					X	
Checking the thrust bearing, counter-thrust bearing and bearing disc						X
Major overhaul 12 000 ... 18 000 operating hours: Check all components and inspect gaps and clearances upon assembly.						X

1) if given
2) visual check and cleaning, if required

Turbocharger on the Two-stroke Engine

Inspection (during operation) in h	24	150	250	3 000	12 000	24 000
Check turbocharger for abnormal noise and vibrations	X					
Check turbocharger and system pipes for leakages (sealing air, charge air, exhaust gas, lube oil)	X					
Check bolts and piping connections for tight seating[1)]				X		

1) Inspection of new or overhauled bolts and piping connections after 250 operating hours required

Maintenance (during operation) in h	24	150	250	3 000	12 000	24 000
Dry cleaning of the turbine	X[1)]					
Wet cleaning[2)] of the turbine			X[1)]			
Clean compressor		X[1)]				
Clean air filter[1)]			X[1)]			

1) or more frequently, as required
2) if given

Maintenance (combined with an engine maintenance) in h	24	150	250	3 000	12 000	24 000
Cleaning the sealing air pipes[1)] in front of the bearing casing				X		
Checking the compressor casing, insert, diffuser and compressor wheel[2)]					X	
Checking the thrust bearing, counter-thrust bearing and bearing disc					X	
Major overhaul 24 000 ... 30 000 operating hours: Check all components and inspect gaps and clearances upon assembly.						X

1) if given
2) visual check and cleaning, if required

Personnel and Time Requirements

Cleaning Work:

	Qualified Mechanic	Assistant
	Required Time in h	Required Time in h
Turbine: Dry cleaning	0.6	—
Wet cleaning	0.6	—
Compressor	0.3	—
Air filter	0.3	—

Removing and Refitting the Turbocharger:

The mounting time for removing and refitting of the turbocharger include the connection of the charge- and exhaust pipes, the lube oil system, the speed transmitter, external sealing air system (if given), Jet Assist (if given) and the given cleaning systems:

	Qualified Mechanic	Assistant
	Required Time in h	Required Time in h
Turbocharger to engine	approx. 6.0	approx. 6.0

Checking Bearing and Bearing Disc:

To check the thrust bearing, counter-thrust bearing and bearing disc the compressor wheel is removed. The compressor casing must not be removed:

	Qualified Mechanic	Assistant
	Required Time in h	Required Time in h
Silencer/Air intake casing	2.0	2.0
Insert	1.5	1.5
Compressor wheel	2.0	2.0
Labyrinth disc	1.0	1.0
Labyrinth ring	1.0	1.0
Bearing and bearing disc	2.0	—
Total hours	**9.5**	**7.5**

Inspection Times for Major Overhaul:

Together with an engine maintenance the turbocharger is subject to a major overhaul every 12 000 to 18 000 operating hours (four-stroke engine) as well as every 24 000 to 30 000 operating hours (two-stroke engine). Here, all components of the turbocharger must be checked and the gaps and clearances must be inspected for dimensional accuracy.

Approx. 20 working hours are to be estimated for all inspection work.

Removing and Refitting	Qualified Mechanic	Assistant
	Required Time in h	Required Time in h
Silencer/Air intake casing	2.0	2.0
Post lubrication tank	1.5	1.5
Insert	1.5	1.5
Compressor casing	2.0	2.0
Compressor wheel	2.0	2.0
Labyrinth disc	1.0	—
Labyrinth ring	1.0	—
Bearing and bearing disc	2.0	—
Gas-admission casing	2.0	2.0
Diffuser	0.5	0.5
Rotor	1.0	1.0
Shroud ring	1.0	—
End cover	0.5	—
Bearing bushes	1.0	—
Inspection of gaps and clearances	ca. 1.0	—
Total hours	**20**	

Service Addresses

The current global MAN Diesel service address list can be obtained from:

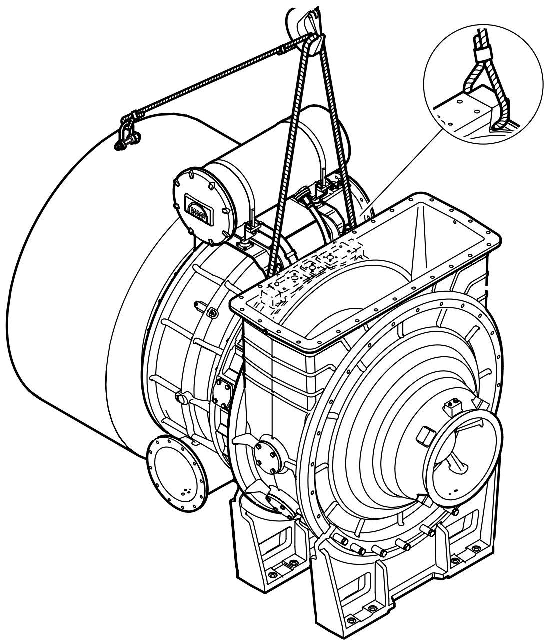
Turbocharger Service Office
Tel.: +49 821-322-1198
Fax.: +49 821-322-3998
E-Mail: tc-service-augsburg@de.manbw.com

13 Affixing and Transport of the Turbocharger

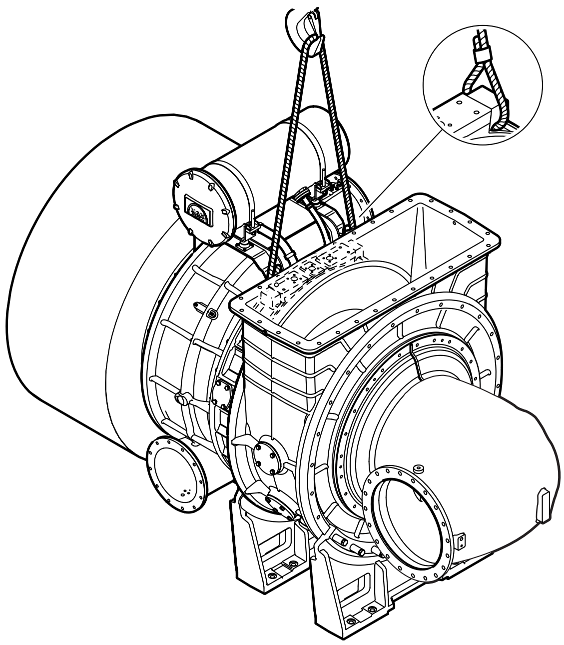
The illustrations show different fixing points for transport of the complete exhaust gas turbocharger (depending on the exhaust gas turbocharger type):

Turbochargers with axial gas-admission casing must be affixed by the two lifting hooks on the bearing casing and by the additional lifting fixture on the silencer in order to hold the turbocharger in balance.

Turbochargers with 90° gas-admission casing can be affixed by the two lifting hooks on the bearing casing (turbocharger is then in balance).



Gas-admission casing axial



Gas-admission casing 90°

The fixing points for the ropes/chains of the lifting tackle are firmly attached on the silencer and bearing casing.

The lifting eye bolts on the assemblies are intended only for lifting of the individual assembly and can not carry the complete weight of the turbocharger!

Note

Weights of Turbocharger see Page 2-4.

Preservation and Packaging

14

Corrosion Prevention

The corrosion prevention includes preservation and packaging of the turbocharger in accordance with the transport and storage conditions to be expected.

Corrosion prevention criteria are the required duration, the transport conditions (land carriage, air or sea freight) and the climatic conditions during the transport as well as the storage at the place of destination.

Preservation is carried out already upon assembly of the exhaust gas turbocharger.

In this, fitted surfaces are treated with anti-corrosion oil, e.g.: Fuchs Anticorit 1, Valvoline Tectil, Teco 6 SAE 30, Exxon Rust Ban 335 or Cylesso 400, Shell Ensis Oil L.

The rotor as well as the interior surfaces of the casings are treated with anti-corrosion agents with low flow properties, e.g.: Fuchs Anticorit 6120-42 E or Anticorit 15 N, Exxon Rust Ban 391 or with moisture-displacing properties, e.g.: Fuchs Anticorit 6120-42 DFV, Valvoline Tectyl 511 M or Tectyl 472.

When using these operating-media-consistent agents, removal of the preservation agent prior to starting operation is not required.

Machine-exterior surfaces are treated with anti-corrosion agents, e.g.: Fuchs Anticorit BW 336, Valvoline Tectyl 846, Exxon Rust Ban 397. These agents must be removed with diesel fuel or petroleum upon assembly prior to the starting of operation.

After preservation, all openings on the exhaust gas turbocharger are sealed air-tight as far as this is possible.

Increased corrosion prevention is achieved (e.g. for overseas, tropics, subtropics) when before closing the openings, vapor-phase corrosion agent (e.g. Branorol 32-5) is sprayed into the gas-intake connection, gas-discharge connection and air-discharge connection at the ratio of 300 cm^3 per 1 m^3 interior space, or when drying agent (bag or block form) is attached to the interior sides of the closing covers. In such cases, the drying agents must be removed upon assembly prior to the starting operation of the exhaust gas turbocharger and the casing must be blown through with compressed air, otherwise toxic fumes can be set free when being heated up.

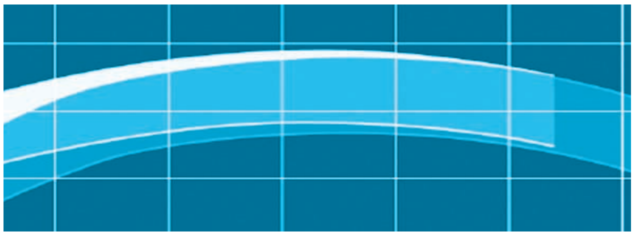
Seaworthy Packaging

The packaging must meet the required degree of corrosion prevention and the conditions for transport and storage.

For overseas shipment and/or extended storage in tropical or subtropical areas, it can be required to additionally shrink-wrap the exhaust gas turbocharger, including a sufficient amount of desiccant bags and moisture indicators within the packing crate, in an aluminum-plastic compound foil.

Instructions on the control measures to be carried out for corrosion protection or post preservation will be supplied or can be requested, as can be detailed instructions on corrosion protection.

15 Training and Documentation



Training Programs

- For engineers
  - Matching of exhaust gas turbochargers
  - Trouble-shooting and corrective action
- For mechanics
  - Practical training in our training center
- Courses for groups available on request

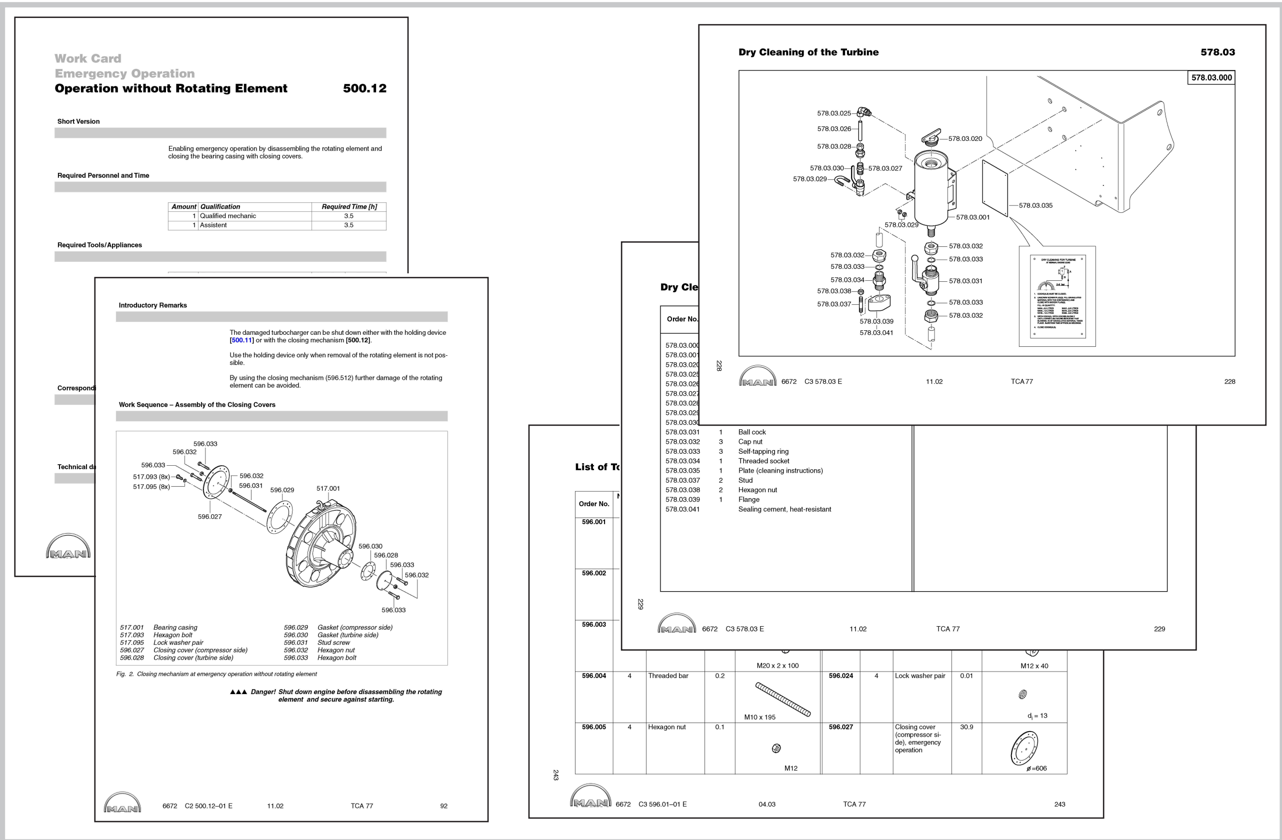
For more information on our training programs, please directly contact the MAN Diesel SE Service Department in Augsburg: tc-service-augsburg@de.manbw.com.

Technical Documentation

In addition to the delivery of an exhaust gas turbocharger, our customers receive a comprehensive technical documentation consisting of:

- Operating manual
- Working instructions (work cards)
- Spare parts catalog
- Spare parts list and tool list
- Certifications
- Records
- Customer information

The technical documentation can also be supplied electronically on request.



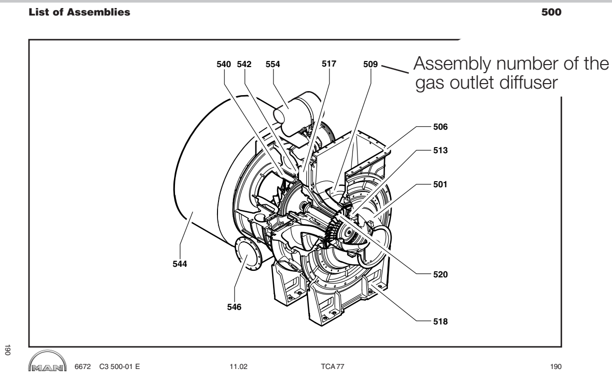
Ordering of Spare Parts

Maintenance and repair work can only be carried out properly when the required spare parts and reserve parts are available.

Spare Parts

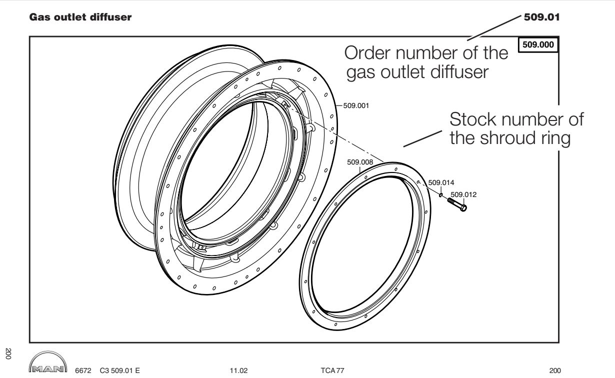
The spare parts catalog is part of the operating manual. It comprises all primary components of the turbocharger.

The pages of the spare parts catalog are organized according to the subassembly system of the turbocharger.
Most **subassemblies** can be determined with help of the Overview of Subassemblies, in front of the spare parts catalog.



Assembly overview with 3-digit assembly number

The **order number**, consisting of the 3-digit assembly number and a 2-digit version number, is located at the top right of the spare parts pages:



Spare parts page with 5-digit stock number

The **stock number** consists of a 3-digit assembly number (for the cleaning devices 5-digit) and a 3-digit position number. Assembly and position number are divided by a dot.

Examples:

Assembly number:	509 (gas outlet diffuser)
Order number:	509.01 (gas outlet diffuser)
Stock number:	509.000 (diffuser, complete) 509.008 (shroud ring)

Reserve Parts

Each turbocharger comes with a set of reserve parts. The reserve parts are packed in a single box. The contents of the box is itemized in the enclosed lists.

The assemblies number of the reserve parts is 595 and for the tools 596. For reordering, the same guidelines apply as for the spare parts.

Ordering

Please direct your order to:

MAN Diesel SE
D-86224 Augsburg

Telephone: +49 821 322 3994
Fax: +49 821 322 3998

To avoid questions and confusion, the following information are required upon ordering:

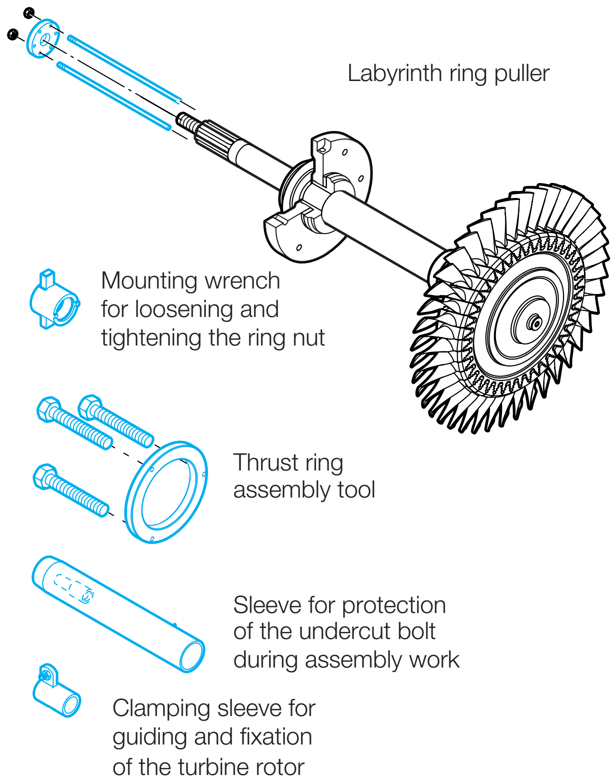
1. Type of exhaust gas turbocharger
2. Works number of the exhaust gas turbocharger (type plate)
3. Stock number of the component
4. Quantity
5. Shipping address

17 Tools

Each turbocharger comes with a set of tools consisting of fitting/unfitting tools, suspension devices, equipment for emergency operation and torque wrenches. This ensures that damages can not occur to the turbocharger in the course of maintenance and repair work, and that the work can be carried out swiftly and effectively.

The tools are packed in one or two boxes. The contents of the boxes are itemized in the enclosed lists.

	Number	Weight (full) of Tool Box in kg
TCA 33		
TCA 44		
TCA 55	1	70
TCA 66	1	90
TCA 77	2	63/73
TCA 88	2	100/125
TCA 99		



Assembly tools

Assembling/Disassembling Devices

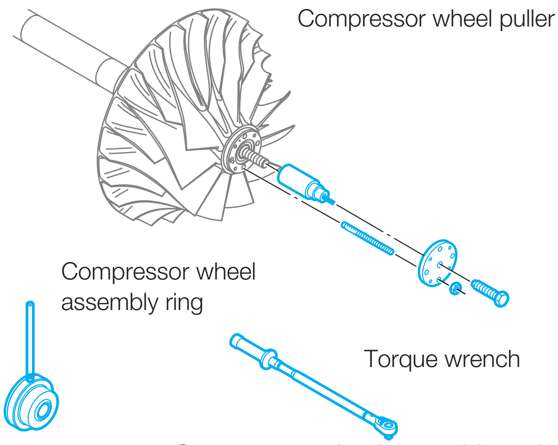
Components that can not be removed and installed by simply loosening the screw connections are removed and installed with pullers and mounting devices, guide rods and lifting eye bolts. These are:

- Turbine rotor
- Compressor wheel
- Insert
- Thrust ring
- Shroud ring
- Labyrinth ring
- Thrust bearing, bearing disc and counter-thrust bearing.

In order to examine the wear condition of the labyrinth ring, the ring nut is released with a specially designed mounting wrench. Afterwards, the labyrinth ring can be released with the labyrinth ring puller.

In order to check the wear condition of the bearing disk in the bearing casing, the thrust bearing must be removed. As a protective measure, a sleeve is mounted onto the undercut bolt of the rotor. Afterwards, the thrust bearing is released with forcing-off bolts so that the bearing disk can be removed.

The compressor wheel is released from the turbine rotor with a puller. Exact reinserting is performed with the help of an assembly ring, whereas fixing is subject to special fixing specifications using a torque wrench.



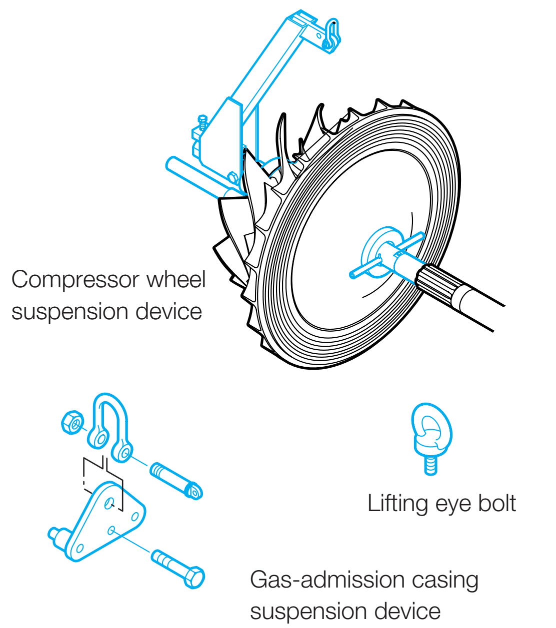
Compressor wheel assembly tools

Suspension Devices

In most cases, standard suspension devices such as shackles and lifting eye bolts are used. These are fastened in the threads or in special bores of the components.

Some heavy components are moved away from the turbocharger by means of specially designed suspension devices:

- Compressor wheel
- Gas-admission casing.



Suspension devices

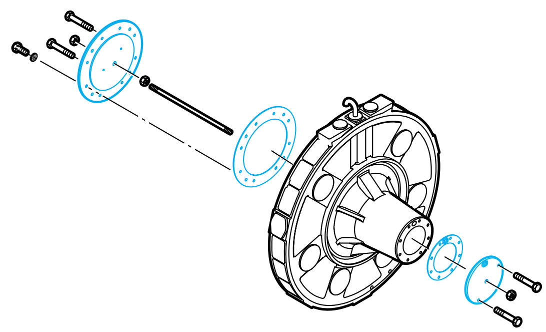
The compressor wheel is slid precisely onto the rotor shaft by means of a specially developed suspension device. The gas-admission casing is fastened to the lifting tackle by means of a shackle and an adapter plate.

Emergency Operation

For emergency operation in case of a turbocharger failure, a closing device for the bearing casing and a securing fixture are included.

With the closing device in emergency operation, the bearing casing is shut with covers and sealed.

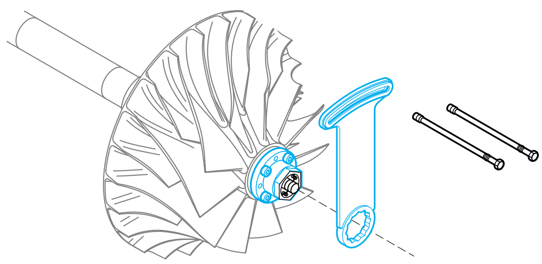
The running gear is removed for this.



Operation with rotating element

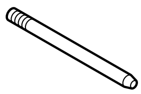
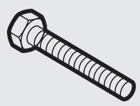
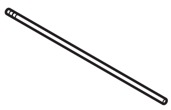
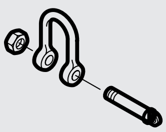
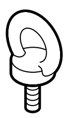
In emergency operation, the securing fixture prevents the rotation of the running gear.

The running gear remains installed.



Operation with holding device

Additional Tools

	Number[1)]	Designation	Use
	5	Guide bar	Insert, labyrinth disk and shroud ring/ nozzle ring
	2	Jack bolt	Compressor wheel and thrust ring
	6	Threaded bar	Compressor wheel and labyrinth ring
	2	Shackles	Gas-admis-sion casing, insert and compressor wheel
	7	Eye bolt	Shroud ring/ nozzle ring, gas-admis-sion casing and labyrinth disk

1) The number of tools can vary for small turbochargers.

General

The assemblies number for tools is 596. When reordering, the same instructions apply as for spare and reserve parts.

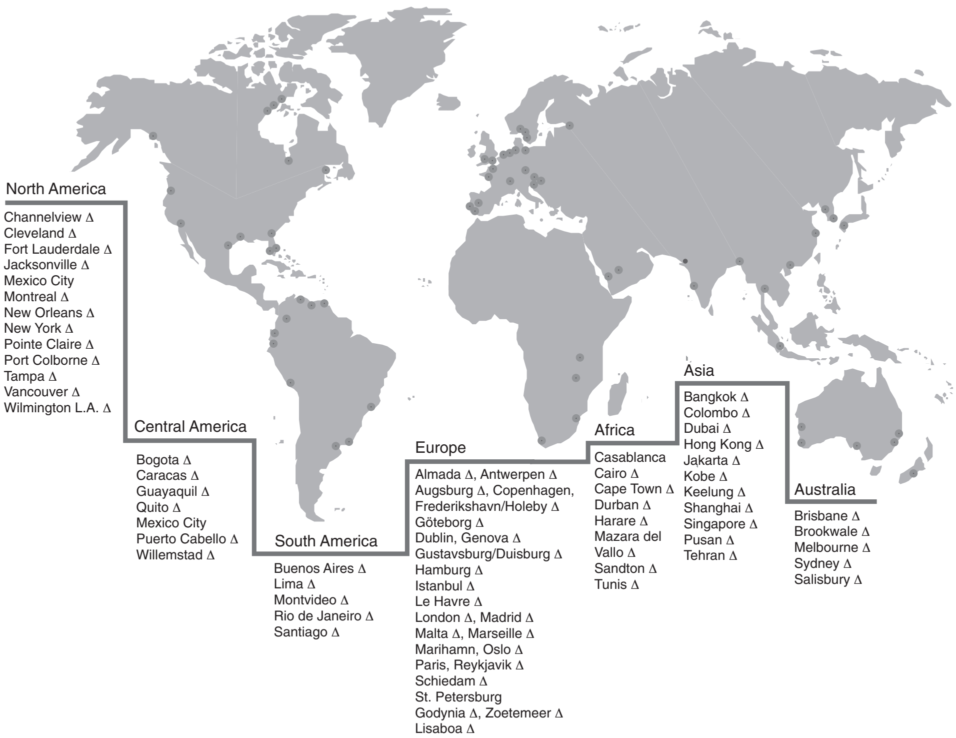
Worldwide Turbocharger Service

- Augsburg Works
  MAN Diesel SE
  86224 Augsburg
  Tel.: +49 821-322-0
  Fax: +49 821-322-33 82
- Hamburg Works
  MAN Diesel SE
  Service Center, Hamburg Works
  Rossweg 6
  20457 Hamburg
  Germany
  Tel.: +49 40-7409-0
  Fax.: +49 40-7409-104
- MAN Diesel Singapore Pte. Ltd.
  29 Tuas Avenue 2
  Singapore 639460
  Tel.: +65 6349-1600
  Fax.: +65 6862-1409
  Fax.: +65 6861-8590 (Service)

- Authorized Repair Shops (ARS)

  Qualified repair shops with MAN Diesel trained service engineers.
- Agents

  Independent companies with close contact to MAN Diesel.
- Over 150 service bases worldwide.
- Swift supply of high grade OEM spare parts.
- 24 Hours around-the-clock service.
- Fast, reliable and competent assistance from experienced, highly-skilled service engineers and mechanics.
- Centralized, computer-controlled spare parts stock in Augsburg.



I Index

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